Feasibility Report Appendixes

December 1991

American River Watershed Investigation, California

VOLUME 2 - APPENDIXES F-L

US Army Corps
of Engineers

Sacramento District
South Pacific Division

American River Watershed Investigation, California

FEASIBILITY REPORT

LIST OF APPENDIXES

American River Watershed Investigation, California

APPENDIX F

Cultural And Paleontological Resources

PROGRAMMATIC AGREEMENT
AMONG THE CORPS OF ENGINEERS, BUREAU OF RECLAMATION, CALIFORNIA STATE HISTORIC PRESERVATION OFFICER, AND THE ADVISORY COUNCIL ON HISTORIC PRESERVATION REGARDING IMPLEMENTATION OF THE AMERICAN RIVER WATERSHED PROJECT

WHEREAS, the Corps of Engineers (COE) and Bureau of Reclamation (BOR) have determined that implementation of the American River Watershed Project (Project) may affect historic properties included in or eligible for inclusion in the National Register of Historic Places, and have consulted the California State Historic Officer (SHPO) and the Advisory Council on Historic Preservation (Council) pursuant to Section 800.13 of the Council's regulations (36 CFR Part 800) implementing Section 106 of the National Historic Preservation Act (16 USC 470f); and

WHEREAS, the American River Watershed Project will provide flood protection and other benefits to the greater Sacramento area and will potentially affect areas within the project construction and operation zones, as well as downstream areas within the American River Flood Plain, where future development may occur as a consequence of the Project (Attachment 1); and *

WHEREAS, the Project may be modified based on public input, congressional authorization, and ongoing negotiations among the primary sponsors (COE, BOR, The Reclamation Board and the Sacramento Area Flood Control Agency) and

WHEREAS, the scope and magnitude of effects to historic properties have not yet been determined because identification and evaluation studies remain to be completed within the area of potential effects (APE); and

WHEREAS, the parties to this agreement recognize that long-term management procedures will be needed to account for the potential development of areas that will be afforded new or increased flood protection as a result of Project implementation; and

WHEREAS, the definitions listed in 36 CFR Part 800.2 are applicable throughout this PA;

WHEREAS, The Reclamation Board of the State of California and the Sacramento Area Flood Control Agency (SAFCA) were consulted and have been invited to concur in this Programmatic Agreement; and,

NOW, THEREFORE, the COE, BOR, California SHPO, Council, The Reclamation Board and SAFCA agree that the undertaking shall be implemented in accordance with the following stipulations in order to take into account any effects of the undertaking on historic properties. The COE is the designated lead (DL) Federal agency for the purposes of implementing this agreement, with the BOR as a cooperating Federal agency, and The Reclamation Board and SAFCA as the cooperating non-Federal sponsors.

STIPULATIONS

The designated lead federal agency will ensure that the following measures are carried out:

1. DEFINITION OF PROJECT AND ASSIGNMENT OF RESPONSIBILITY

As currently configured, the Project consists of the 200-Year Protection Alternative defined in the COE's Draft Feasibility Report and Joint EIS/EIR for the American River Watershed Investigation, California (April 5, 1991). This alternative includes construction of a 545,000 acre foot flood control dam at Auburn, raising or constructing levees in the Natomas area, relocation of portions of State Highway 49, and raising or replacing bridges.

A. If the nature of the Project changes, the DL will consult with the SHPO, The Reclamation Board, SAFCA, and the BOR in a timely manner to determine the need for modification of the APE and scope of historic property identification, evaluation, and treatment measures defined in Stipulations 2-4 below. If agreement cannot be reached about the scope of these modifications, the COE shall consult the Council pursuant to Stipulation 10 prior to making an irreversible commitment to such changes.

B. In the event that a change in the DL is proposed, the COE will immediately notify the other parties to this agreement. The DL will request an amendment to the PA if changes in the DL becomes necessary because of congressional authorization.

2. INVENTORY OF HISTORIC PROPERTIES

The DL will consult with the SHPO and the cooperating Federal agency to review historic property identification studies already conducted in the Project's APE and determine the scope and extent of further actions needed to complete the inventory. The DL shall then ensure that necessary actions are taken to complete the historic property inventory of the APE in a manner consistent with the Secretary of the Interior's Standards and Guidelines for Identification (48 FR 44720-23), the National Park Service publication The Archaeological Survey: Methods and Uses (1978: GPO Stock No. 024-016-00091), and guidance offered by the SHPO.

The DL will ensure that archaeological properties identified during the inventory are recorded or updated on California Department of Parks and Recreation (DPR) Form 422 in accordance with the Office of Historic Preservation's (OHP's) California Archaeological Inventory Handbook for Completing an Archaeological Site Record (March 1989), and that those forms have been submitted to and permanent site numbers have been assigned by the appropriate Information Center of the California Archaeological Inventory prior to submission of inventory reports for review. Historic resources located during the inventory shall be recorded on DPR Form 523 in accordance with the OHP's Instructions for Completing California Historic Resources Inventory Forms (March 1984).

The DL shall ensure that all inventory and survey reports are prepared and circulated for review in accordance with the provisions contained in Stipulation 5 prior to taking any actions that might affect historic properties.

3. HISTORIC PROPERTY EVALUATION

The DL will consult with SHPO and the cooperating Federal agency to determine the scope and timing of the studies needed for purposes of evaluating the National Register eligibility of cultural resources in the Project's APE prior to initiating any activities that might affect historic properties. Where adequate provisions can be designed to ensure that cultural resources will not be affected, no evaluation will be required.

The DL will ensure that all cultural resources which will be affected by the Project are evaluated to determine their eligibility for inclusion in the National Register in consultation with the SHPO and the cooperating Federal agency, taking into account the Secretary of the Interior's Standards and Guidelines for Evaluation (48 FR 190:44729-44738), National Register Bulletin 15: How to Apply the National Register Criteria for Evaluation (1991), Guidelines for Archeological Research Designs (Office of Historic Preservation 1991), and other guidance offered by the SHPO. All evaluations will be directed by a research design and plans developed by the DL in consultation with other parties to this agreement.

Once evaluative excavations have been initiated at those archaeological sites determined to require excavation by the DL, in consultation with other parties to this agreement, the DL will ensure that recovered materials are fully analyzed according to the research design and plan that was prepared to guide the excavation. Changes in the Project will not relieve the DL of the responsibility to ensure completion of individual resource evaluations once materials have been removed from an archaeological site.

By mutual agreement among the COE, BOR, and SHPO, evaluative studies may be phased. The DL shall ensure that the evaluative study or studies are prepared and submitted for review according to the provisions of Stipulation 5. No further consideration need be given to properties that the DL, SHPO, and cooperating Federal agency agree are not eligible. If an evaluation results in the identification of a property or properties that the DL, SHPO, and cooperating Federal agency agree are eligible for the National Register, the DL shall ensure that they are treated in accordance with Stipulation 4.

4. HISTORIC PROPERTY TREATMENT PLAN(S) (HPTPs):

The DL will consult with the SHPO, Council, The Reclamation Board, and the cooperating Federal agency to develop a mutually acceptable HPTP or HPTPs for all National Register eligible and listed properties in the Project's APE. Separate HPTPs may be prepared for individual components of the Project if agreed to in advance by the SHPO, COE, BOR, and The Reclamation Board. Each HPTP will be submitted SHPO and Council for review according to the procedures defined in Stipulation 5. Following its acceptance by the reviewing parties, the DL will ensure that the HPTP is implemented.

Each HPTP will take into account the principles, standards, and guidance in Archaeology and Historic Preservation; Secretary of the Interior's Standards and Guidelines (48 FR 44716-44742), the Council's publication, Treatment of Archaeological Properties (1980), and guidance offered by the SHPO. Each HPTP will consider, at a minimum, the following issues:

A. The actions that will be taken to protect and conserve historic properties. These protective measures may include, but should not necessarily be limited to monitoring; capping; fencing; land use policy and planning techniques such as zoning restrictions, and transfer of development rights; and other appropriate measures.

B. The need for data recovery at sites subject to adverse effects. Where data recovery is required at a National Register eligible or listed archaeological site or sites, the HPTP shall include a research design to guide that work. The research design shall take into account the Office of Historic Preservation's (1991) Guidelines for Archaeological Research Designs, and shall specify the types and amounts of analysis that will be conducted, how reports will be prepared and distributed, where recovered materials will be curated, how interested persons will be invited to participate, what efforts will be taken to interpret the results of the investigation(s) to the public, and a schedule for accomplishing the study or studies.

C. Any property, properties, or portions of those properties that will be destroyed or altered without data recovery or other treatment;

D. A schedule for implementation of all the treatment measures defined in the HPTP.

5. REPORT FORMAT AND REVIEW:

The DL shall ensure that all documents prepared to satisfy the terms of this agreement are responsive to contemporary professional standards, the Secretary of the Interior's Format Standards for Final Reports of Data Recovery Programs (42 FR 5377-79), and the OHP's Archaeological Resource Management Reports (ARMR): Recommended Contents and Format (December 1989). Archaeological sites shall be referred to by their permanent trinomial designations in all reports. Precise historic property locational information shall not be placed in documents for public distribution if the release of those data may adversely affect the properties.

A. Unless otherwise agreed to, each document prepared to satisfy the stipulations of this agreement will be submitted by the DL to the cooperating Federal agency, SHPO, Council, and The Reclamation Board for a 30 day review period commencing on the day of its receipt by the reviewing party. If the reviewing parties have no objection to the findings of the document, or if they fail to comment in the allotted time, the DL may assume acceptance of the document and implement subsequent actions required for compliance with this agreement, or, if no further actions are required, the DL may begin construction of the Project or Project component covered by that document.

B. If objections are raised in the review period, the DL shall consult with the objecting party to remove those concerns. If objections cannot be resolved to the satisfaction of all reviewing parties, the DL shall consult the Council pursuant to Stipulation 10. The DL will then ensure that the revised document is implemented in a manner that takes into account the Council's comments.

C. Copies of each accepted final report will be submitted by the DL to the Council, SHPO, The Reclamation Board, cooperating Federal agency, and appropriate Information Center(s) of the California Archaeological Inventory.

6. PARTICIPATION OF INTERESTED PERSONS:

The public shall have an opportunity to comment on the contents and implementation of this agreement pursuant to 36 CFR 800.1(c) (2) (iv), 800.13(c), and 800.14. Following its execution, the DL will distribute copies of this agreement to persons and organizations likely to be interested in the management of cultural resources that may be affected by the Project. Those interested parties should include appropriate Native American individuals and groups, local historical and archaeological societies, agencies that manage cultural resources which may be affected by the Project, preservation groups, and other persons and organizations likely to have an interest in the management of historic properties within the Project's APE. These prospective interested persons shall be given 30 days to comment on the agreement from the time they receive a copy of it.

The DL shall provide copies or a synopsis of the comments it receives to the other parties to this agreement, along with a plan defining how interested members of the public will be given opportunities to comment on the implementation of this agreement. The plan will include provisions for involving the Most Likely

Descendants of Native American groups associated with the Project APE, as identified through consultation. The views of the Descendants will be considered and integrated into planning and conducting any work involving the disturbance of scientific excavation of historic properties associated with Native Americans.

7. CURATION OF RECOVERED DATA:

The DL shall ensure that all materials and records resulting from the implementation of this agreement are curated or otherwise treated in accordance with the Secretary of Interior's Standards and Guidelines, 36 CFR Part 79 and the Archaeological Resources Protection Act (PL 96-95). A curatorial agreement or other provisions for the disposition of recovered data shall be reached between the DL, a specific curatorial facility, and other interested parties prior to the implementation of any subsurface archaeological studies that may be required under the terms of this agreement.

8. PROFESSIONAL QUALIFICATIONS:

All studies conducted under the terms of this agreement will be carried out or directly supervised by appropriately trained persons who meet or exceed the Secretary of the Interior's Professional Qualifications Standards for the particular field of study required in that investigation. The COE and BOR will ensure that they retain staff meeting the aforementioned standards for the purposes of monitoring and implementing the terms of this agreement.

9. REVIEW OF IMPLEMENTATION AND AMENDMENT OF AGREEMENT:

All parties to this agreement shall confer or meet annually on the anniversary of its signing unless it is mutually agreed that this is unnecessary. This annual conference or meeting will be held for the purpose of reviewing implementation of the terms of this agreement and to determine whether revisions of the agreement are needed. If a meeting at the Project site is required, the DL will provide sufficient travel funds to allow for Council participation. The DL will provide an annual report of activities for review by all parties to the agreement at least 30 days prior to the anniversary date. If revisions are needed, the parties to this agreement shall consult in accordance with 36 CFR 800.13 to make such revisions.

Any party to this agreement may also request that it be amended by notifying the other parties, whereupon all of the parties will consult in accordance with 36 CFR 800.13 to consider such revisions. This request may be initiated at any time during the implementation of this agreement.

10. DISPUTES:

Should any of the parties to this agreement object within 30 days to any documents provided for review pursuant to its terms, the DL shall consult with the objecting party(ies) to resolve their concern. If the DL determines that the objection cannot be resolved, it shall submit documentation relevant to the dispute to the Council with a request for comments pursuant to this stipulation. Any Council comment provided within 30 days of such a request will be taken into account by the DL in accordance with 36 CFR 800.6(c) (2) with reference only to the subject of the dispute. The DL's responsibility to carry out actions unrelated to the dispute will remain unchanged.

11. FAILURE TO CARRY OUT THE TERMS OF THIS AGREEMENT:
If the DL fails to carry out the terms of this agreement, it must comply with 36 CFR 800.4 through 800.6 for the Project or any aspect of the Project that could affect historic properties before taking or sanctioning any action.

12. TERMINATION:

Any party to this agreement may terminate it by providing 30 days written notice to the other parties, provided that the terminating party has consulted with the other parties prior to seeking termination and has sought agreement on amendments or other actions that would avoid termination. In the event of termination, the DL shall comply with 36 CFR 800.4 through 800.6 with regard to implementation of the Project or any aspect of the Project that may affect historic properties.

CONCLUSION

Execution and implementation of this agreement evidences that the COE and BOR have afforded the Council a reasonable opportunity to comment on the management of historic properties affected by the American River Watershed Project and that the COE and the BOR have taken into account the effects of the Project on such properties in compliance with Section 106 of the National Historic Preservation Act and its implementing regulations (36 CFR 800).

*Note: Attachment 1 of the Programmatic Agreement is Chapter 2 of the EIS. It is not included in this appendix.

ADVISORY COUNCIL ON HISTORIC PRESERVATION

BY: Robert D. Bush DATE: 12/13/91

Robert Bush
Executive Director

CORPS OF ENGINEERS, SACRAMENTO DISTRICT

BY: Laurence R. Sadoff DATE: 25 Nov 91

Laurence R. Sadoff, Colonel
District Engineer

BUREAU OF RECLAMATION, MID-PACIFIC REGIONAL OFFICE

BY: Roger K Patterson DATE: 11/27/91

Roger K. Patterson
Regional Director

CALIFORNIA HISTORIC PRESERVATION OFFICER

BY: Kathryn Gualtieri DATE: 12/5/91

Kathryn Gualtieri
California State Historic Preservation Officer

THE RECLAMATION BOARD

BY: Rodney G. Mayer DATE: 11/25/91

for Raymond E. Barsch
General Manager

SACRAMENTO AREA FLOOD CONTROL AGENCY

BY: William H. Edgar DATE: 11/25/91

William H. Edgar
Executive Director

PRELIMINARY
PALEONTOLOGICAL EVALUATION:

AMERICAN RIVER
WATERSHED INVESTIGATION

Contract No. DACW05-91-P-2493

Submitted to:

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APPENDIX A

Biota Lists for Three Sacramento Area Quaternary Fossil Localities

Taxon	H	T	C
Pseudotsuga sp.		x	
Platanus sp.		x	
Salix sp.		x	
Archoplites sp.		x	
Cyprinidae		x	
Bufo sp.	x		x
Rana sp.	x	x	x
Clemmys marmorata	x	x	
Gerrhonotus multicarinatus	x		x
Sceloporus graciosus	x		
Colubridae		x	
Crotalus viridis	x		sp.
?*Branta canadensis*		x	
Placerias gigas	x		
Nettion carolinensis	x		
Cathartes aura	x		
Catharista shastense type	x		
?*Gymnogyps (Coragyps) occidentalis*	x		
Archaeobuteo ferrugineus	x		
Buteo regalis	x		
Hypomorphinus milleri	x		
Geranoaetus sp.	x		
Oreortyx picta	x		
Calipepla californica	x		
Colaptes auratus	x		
Corvus corax	x		
Cyanocitta stelleri	x		
?*Euphagus cyanocephalus*	x		
Aves, undetermined		x	
Antrozous pallidus			x
Scapanus latimanus	x	x	
Homo sapiens	x		

APPENDIX A. (Continued)

Megalonyx sp.	x		
Nothrotheriops shastense hawveri type	x		
Paramylodon (Glossotherium) harlani	x	x	
Lepus californicus	x		sp.
Sylvilagus sp.	x	x	
Brachylagus idahoensis			x
Aplodontia rufa	x		
Spermophilus beecheyi	x	cf.	x
Eutamias sp.			x
Thomomys bottae	sp.	x	sp.
Perognathus sp.		x	
Peromyscus boylii	x		sp.
Reithrodontomys sp.		x	
Neotoma fuscipes	x	sp.	x
Microtus sp.	x	x	
Martes sp.	x		
Mephitis mephitis	x		x
Canis dirus	nr.	x	x
Canis latrans	x	x	
Procyon lotor	x		
Ursus sp.	x		
Smilodon floridanus	x		
Felis hawveri type (=*concolor*)		x	
Felis concolor	sp.		x
Mammut sp.	x		
Mammuthus sp.	x	x	
Equus ?occidentalis	x	sp.	
Camelop hesternus		x	
Odocoileus hemionus	sp.	sp.	x
Euceratherium ?collinum	x		
Bison sp.		x	
Bison cf. *B. antiquus*		x	

H=Hawver Cave, El Dorado Co.; T=Teichert Gravel Pit East #1-2, Sacramento Co.; C=Cool Quarry, El Dorado Co.; x=occurrence of the listed taxon; sp.=material identified only to generic level; ?, cf., nr.=tentative identification.

American River Watershed Investigation, California

APPENDIX G

Section 404 Evaluation

SECTION 404(b)(1) EVALUATION

AMERICAN RIVER WATERSHED INVESTIGATION, CALIFORNIA

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SECTION 404(b)(1) EVALUATION
AMERICAN RIVER WATERSHED INVESTIGATION, CALIFORNIA

PART 1 INTRODUCTION

In accordance with Section 404 of the Clean Water Act (USC 1344), and other pertinent laws and regulations, the placement of dredged or fill materials below ordinary high water into waters of the United States or their associated wetlands requires an evaluation of water quality considerations related to the action. Construction of a flood control dam proposed under the Selected Plan would require the placement of fill material into the waters of the North Fork of the American River and in the Natomas area where levee construction is proposed. Since these waters are protected under the Federal Clean Water Act (Act), the project must comply with applicable provisions of Section 404 of the Act.

The following evaluation of water quality impact has two objectives. The first objective is to satisfy the 404 Guidelines as developed by the Environmental Protection Agency (EPA) under Section 404(b)(1) which prohibits all avoidable discharges into regulated waters and requires project sponsors to select "the least environmentally damaging practicable alternative that will achieve the basic project purpose."

The second objective is to satisfy the requirement of Section 404(r) of the Federal Clean Water Act which provides that Congress may exempt the project from further regulation by Federal and state water quality control agencies following the project's authorization by Congress. In connection with any Federal project specifically authorized by Congress, Section 404(r) enables Congress to determine whether a proposed discharge into Federally regulated waters is appropriate. However, this authority may be exercised only if, before the discharge occurs and before any funds are either authorized or appropriated for the project, Congress is presented with an environmental impact statement which discloses the effects of the discharge and evaluates the 'practicability' of the avoidance or at least the lessening of these effects. An EIS/EIR has been prepared for submittal to Congress prior to any action on the Selected Plan, and is intended to satisfy the procedural and informational requirements of Section 404(r). The information contained within the EIS/EIR documents the environmental effects of the alternatives evaluated as well as the Selected Plan. This appendix details the water quality and related information used in the 404(b)(1) evaluation specifically to demonstrate that the selected (recommended) plan, 200-year flood protection, is in compliance with the Clean Water Act. This information enables Congress to evaluate the plan in light of EPA's 404(b)(1) guidelines and in regard to whether the Selected Plan represents the least environmentally damaging (practicable) approach to achieving the goals and purposes of the Project. As noted above and as concluded by the District Engineer in his report, authorization of the project by Congress will include an exemption from further regulation by Federal and State water quality control agencies.

ALTERNATIVES CONSIDERED

The feasibility and environmental documents prepared in connection with the American River Watershed Investigation (ARWI) focus on the following alternatives, each of which is more fully described Chapter 2 of the EIS/EIR and Chapter II of the Main Report. A full comparison of the effects of the alternative plans is contained in the EIS/EIR.

200-Year Alternative (Selected Plan)

The 200-year alternative would involve: construction of a 425-foot (about 499 ft, mean sea level [MSL]), flood control dam with a storage capacity of 545,000 acre feet near the City of Auburn in Placer County; raising portions of the levees around the perimeter of the Natomas basin from 1 to 3 feet; constructing new levees along lower Arcade and Dry Creeks; constructing a high volume pump station with low flow sluices on the Natomas East Main Drainage Canal (NEMDC) near the mouth of Dry Creek; constructing a detention basin in the northeast corner of Natomas (Sutter County); and replacement of bridges along Highway 49 and Ponderosa Way near the dam site, and on Main Avenue at the NEMDC crossing. Impacts from all of the alternatives would be essentially the same for the Natomas area. Construction of the flood detention dam and related features for this alternative would result in the loss of 227 acres of vegetation. Use of the facility over the period of analysis would result in the loss of 1700 acres from inundation and sloughing.

400-Year Alternative (NED Plan)

The 400-year alternative would involve the same features as described for the 200-year alternative except the dam would be about 500 feet in height (574 ft MSL) and have a storage capacity of 894,000 acre feet. Impacts from this alternative would be similar to those described for the selected plan. The amount of materials and dam footprint would be slightly increased and the quarry area would be enlarged resulting in the loss of 254 acres of habitat. However, the operational impacts could be less (700 acres) since the 400-year dam would have a lower design release with slower drawdown of impounded flood waters and it would thus be less likely to trigger soil sloughing in the inundation zone, resulting in less combined impact from the construction and operation of this alternative.

150-Year Alternative

The 150-year alternative substitutes flood control measures along the lower American River and in Folsom Reservoir for the upstream storage capabilities discussed in connection with the 200-year alternative. The 150-year alternative would involve increasing the design release from Folsom Dam from 115,000 cfs to 180,000 cfs. This would require raising 11 miles of levees and riprapping 10 miles of bank and/or levee slopes in the American River Parkway, lengthening the Sacramento Bypass, and raising levees in the Sacramento and Yolo Bypasses. In addition, seasonal flood storage in Folsom Reservoir would be increased from 400,000 acre feet to 650,000 acre feet. However, the flood control plan remains essentially the same for the Natomas area regardless of the main stem protection alternative. Impacts concerning the Natomas area are similar to the 200-year flood protection alternative.

100-year (FEMA) Storage Alternative

This alternative would require permanent reoperation of Folsom Reservoir to increase seasonal flood control storage from 400,000 acre feet to 590,000 acre feet. No structural modifications to the lower American River levee system would be required. Levee improvements in the Natomas basin would be substantially the same as described for the 200-year alternative above. No fill material would be discharged under this alternative. However, significant reductions in the amount of riparian and wetland habitat and significant reductions in the salmon fishery could occur as a result of the reduced flows in the lower American River associated with the reservoir reoperation.

100-Year (FEMA) Levee Alternative

This alternative would require modification of the levee system to accommodate objective releases of 145,000 cfs that includes added levee raising and channel armoring similar to that described for the 150-year alternative; however, no increased flood water storage would be necessary. Therefore, the construction impacts associated with this alternative would be substantially the same as the 150-year alternative, but the long-term losses resulting from reoperating Folsom Reservoir on a seasonal basis would not occur. Levee improvements in the Natomas basin would be substantially the same as described for the 200-year alternative above.

100-Year (FEMA) Levee/Storage/Spillway Alternative

This alternative would require improvement and reinforcement of 10 miles of levees to accommodate objective releases of 130,000 cfs from Folsom Reservoir. Therefore, construction impacts would be similar (slightly less) to those described for the 150-Year Alternative. In addition, the spillway gates on Folsom Dam would be lowered in order to allow releases earlier during the flood event. An increase in the volume of seasonal flood reservation in Folsom Reservoir from 400,000 acre feet to 470,000 acre feet would be necessary. The spillway gates on Folsom Reservoir would be lowered several feet. Therefore, some long-term losses in the acreage of riparian habitat and the fishery would result, although to a lesser extent than described for the 100-year storage alternative and the 150-year alternative, which would require seasonal flood reservations of 590,000 and 650,000 acre feet, respectively. Levee improvements in the Natomas basin could be substantially the same as described for the 200-year alternative above.

PART 2 PROJECT DESCRIPTION 200-YEAR FLOOD PROTECTION

1. **Project Location**. The project area concentrates on the American River drainage basin and covers approximately 2,100 square miles of watershed northeast of Sacramento, California, including portions of Sacramento, Sutter, Yolo, Placer, and El Dorado Counties.

2. **General Description**. The Selected Plan involves: (1) constructing a 425-foot high flood control dam with a storage capacity of 545,000 acre feet on the North Fork American River near the City of Auburn in Placer County; (2) relocating State Highway 49 and Ponderosa Way; (3) constructing levee improvements along the Natomas East Main Drainage Canal, Pleasant Grove Creek Canal, Natomas Cross Canal, lower Arcade and Dry Creeks, and Sankey Road; (4) constructing a high volume pump station with low flow sluices on the Natomas East Main Drainage Canal (NEMDC) near the mouth of Dry Creek; (5) constructing a 3,000 acre-foot detention basin in the northeast corner of Natomas; and (6) constructing pedestrian/bike and equestrian trails along areas in Natomas where levees would be modified.

3. **Authority and Purpose**. The basic authority of the study is the Flood Control Act of 1962 (Public Law 87-874). Additional authority is contained in the Fiscal Year 1987 Appropriations Act and the Fiscal Year 1988 Continuing Appropriations Act. The purposes are to:

a. Study alternative means for flood control in the American River watershed, in Natomas and in the lower Dry Creek watershed.

b. Assume that the multipurpose Auburn Dam, as previously authorized, will not be constructed.

c. Evaluate incidental water, power, and recreational benefits as they relate to a peak-flow flood control facility on the North Fork American River upstream from Folsom Dam.

d. Analyze current projected water demands for the American River basin.

4. **General Description of Fill Material**.

a. Dam Construction Material. Construction of the flood control dam at Auburn would require placement of approximately five million cubic yards of concrete mix composed of crushed aggregate, cement and other amendments (pozzolan, sand). The aggregate would be obtained from the Old Cool Quarry, located on the east side of Highway 49 about 5 miles from the dam site, and transported to the site using a fixed conveyor system to be crushed to size and mixed with the cement and amendments to form concrete.

b. Levee Construction Material. Material required for the construction and raising of levees would be excavated from nearby borrow sites, consisting of material similar to that which is found at the levee sites and certified as being free of contaminants.

c. Pump Station Construction Material. For the installation of a pump station and gate structure on the NEMDC, the station would be constructed using watertight forms or pre-cast concrete.

d. Trail Construction Material. The recreational pedestrian/bicycle and equestrian trails, which would be placed along and within the NEMDC, would be constructed with fill material obtained from local borrow sites, using similar material to that found at the site.

5. **Description of the Proposed Discharge Sites**.

a. Dam Construction.

(1) Location. The proposed dam site would be located on the Upper American River at River Mile (RM) 20.1 (see Plate 14 of the Main Report).

(2) Size. In the upper American River area, approximately 8,000 acres would be required to construct, operate and maintain the proposed flood control dam and related facilities. The dam would have a maximum height above the streambed of 425 feet (499 ft MSL), a crest length of 2,600 feet, and a base width of 400 feet.

(3) Type of site. The area around the proposed dam site consists of canyon-type lands ranging from gently sloping to extremely steep along the Middle and North forks of the American River. A vast majority of this land is owned by the Federal government as part of the authorized multi-purpose Auburn Dam. Construction roads and staging areas, a diversion dam and other features previously built for the U.S. Bureau of Reclamation (USBR) project exist at RM 20.1 and the site is already cleared.

(4) Type of habitat. Historically, the riverbed and bars of both the Middle and North Forks of the American River have been extensively explored for mining from as early as 1884. The area disturbed by the mining boom was eventually abandoned and left to recover on its own. Today the area serves as a transitional zone between middle elevation foothill grassland, hardwood and forest communities and the higher montane, largely evergreen conifer-dominated forest communities. There are no endangered species recorded within the proposed quarry area or at the proposed dam site. Therefore, the discharge will not jeopardize the existence or modify habitat of a threatened or endangered species.

(5) Timing and duration of discharge. During construction, water would continue to flow undisturbed through the existing diversion tunnel constructed for the USBR multi-purpose Auburn Dam. Upon completion of the flood control dam, normal flows would be diverted through the two lower sluices in the dam and the diversion tunnel blocked. The anticipated schedule is 5-6 years for construction of the flood control dam and appurtenances.

b. Levee Construction.

(1) Location. The Natomas portion of the project consists of the construction of levee improvements at several locations along the Natomas East Main Drainage Canal, Pleasant Grove Creek Canal, Natomas Cross Canal, lower Arcade and Dry Creeks, and Sankey Road, and the construct a levee on the north side of Dry Creek near the Natomas East main Drainage Canal (see Plate 14 of the Main Report).

(2) Size. The levee improvements consist of raising 40,800 linear feet of existing levee, constructing 7,000 linear feet of new levee, and extending 2,400 linear feet of existing levee.

(3) Type of site. The Natomas basin contains lands which were reclaimed from the historic Sacramento and American River flood plain in 1917 by means of a system of canals and levees constructed around the perimeter of the basin.

(4) Type of habitat. Urbanization and agricultural production shape the current Natomas landscape which is characterized by agricultural as well as uncultivated and

natural vegetation types, including wooded and non-wooded riparian/wetland cover types. Wooded riparian sites generally occur along the borders of drainage canals and often are associated with narrow strips of emergent wetland vegetation.

(5) Timing and duration of discharge. Most levee-related work will be accomplished on top of the existing levees and will increase levee heights by about 1.5 feet. Levee construction is scheduled to be the first work contracted for the project and is estimated to take an 18-month period to complete. (For the most part, levee work will be performed during dry months, normally April through October, to minimize construction impacts on water resources.)

PART 3 FACTUAL DETERMINATIONS 200-YEAR FLOOD PROTECTION

1. **Physical Substrate Determinations**:

a. Substrate elevation and slope:

(1) Upper American River. At the dam site, there is a potential slide area located near the right abutment of the proposed alignment of the dam. This area may require removal or stabilization in connection with preparing the dam foundation.

The Old Cool Quarry is in a disturbed condition owing to a long history of quarrying activities. Any erosion or lateral displacement likely to result from mining operations would be mitigated by implementing an appropriate reclamation plan.

Periodic filling and emptying of the canyon area behind the flood control dam could result in erosion and soil slippage in the inundation zone. These effects are described in the Reservoir Rim and Slope Stability Study (Appendix M) and the Analysis of Potential Vegetation Mortality Associated with the Proposed Auburn Flood Control Dam (Appendix Q).

(2) Natomas. The levee alterations would conform to existing slopes. Materials discharged to construct the new levees on the lower portions of Dry and Arcade Creeks would be stabilized to prevent surface erosion. No erosion or lateral displacement is anticipated at the pump station on the NEMDC since the station would be constructed with reinforced concrete. A revegetation program would be implemented to stabilize exposed soils.

b. Sediment (Material) type:

(1) Upper American River. Construction of the proposed flood control dam at Auburn would require placement of approximately 5 million cubic yards of a concrete mix composed of crushed aggregate, cement and other amendments (pozzolan, sand).

The cement and amendments would be delivered to the site from off-site sources. The aggregate would be obtained from the Old Cool Quarry, an operation located north of the town of Cool on the east side of Highway 49 about 5 miles from the dam site. The quarried gravel would be transportedto the dam site using a fixed conveyor system to be crushed to the appropriate size and mixed with the cement and amendments to form concrete. After the crushing, the aggregate would vary in particle size, shape, and degree of compaction of the original gravel.

(2) Natomas. The Natomas portion of the project consists of the following components: (1) raising the levees of the NEMDC to increase channel capacity; (2) raising and constructing levees in the Arcade Creek and Dry Creek flood plains near the NEMDC in order to control any backwater effects produced by the NEMDC improvement work; (3) installing a pump station and gate structure on the NEMDC just above its confluence with Dry Creek to control southerly flows reaching the NEMDC from the Pleasant Grove Creek Canal and to manage northerly flows traveling up the NEMDC from below Dry Creek; (4) spot improvements needed along three segments of the west levee of the Pleasant Grove Creek Canal to prevent run-off from Pleasant Grove Creek and other tributary drainage systems east of Natomas from entering the basin; (5) spot improvements needed along three segments of the south levee of the Natomas Cross Canal (NCC) to contain waters from drainage streams north and east of Natomas; (6) creation of a weir and a 300 acre detention area in the northeast corner of the basin to compensate for any backwater effects that the spot improvements could have on lands in the Pleasant Grove Creek area east of Natomas; and (7) construction of a recreational bicycle trail.

The material used for levee construction and raising would be excavated from nearby borrow sites, consisting of material similar to the material found at the levee sites and certified as being free of contaminants. The pump station would be constructed using watertight forms or pre-cast concrete. In the construction of the recreational bicycle trail, which would be placed along and within the NEMDC, all imported fill material would be obtained from local borrow areas, using similar material to that found at the site.

c. Dredged/fill material movement:

(1) Upper American River. The fill material used in the construction of the dam would be reinforced roller compacted concrete and is not expected to move. However, due to the active fault zone at the dam, the dam would be designed to seismic safety standards which would allow for a maximum displacement of 9 inches during the maximum credible earthquake.

(2) Natomas. The fill material used in raising the existing levees would be compacted and seeded to reduce soil erosion. New levees would also be compacted and seeded.

d. Physical effects on benthos See effects on aquatic food web in 5.d. below.

e. Other effects. None.

f. Actions taken to minimize impacts:

(1) Upper American River. Excavation would be restricted to the smallest practicable area to secure the required materials. The proposed dam would be located at River Mile (RM) 20.1. There are more narrow channel segments along the North Fork between the limit of Folsom Reservoir and the confluence of the North and Middle Forks where the dam could be located. Three alternative dam sites have been evaluated: RM 22.1, RM 19.2, and RM 19.0. It has been estimated by the USBR that construction of a dam at any of these alternative dam sites would require up to 30 percent less material than the proposed site. However, in order to construct a dam at these sites, new construction roads and staging areas, a new diversion dam and other features would be required. This would significantly impact the surrounding vegetation and river. Because these feature are already constructed and the land is already cleared at RM 20.1, this site represents a viable, least environmentally damaging location for the proposed dam.

(2) Natomas. The amount of fill material used would be limited to only that which is necessary to raise existing levees to their designed elevations and slopes. New levees along the north bank of Dry Creek and the south bank of Arcade Creek would also be constructed in a manner to minimize impacts and still meet design standards. The fill material used to raise existing levees would be placed on the levee crown and landside levee slopes above the ordinary high water elevation. As a result, no impacts to the physical substrate are expected. New levees would require the placement of material below the ordinary high water elevation. Levee slopes would be seeded with grasses to reduce erosion. The pump station would be constructed with pre-cast or sealed-form concrete to avoid introduction of excessive sedimentation into the waterway.

2. **Water Circulation/Fluctuation/Salinity Determinations**:

a. Water: (Also see 3. b. below.)

(1) Upper American River. Primary impacts from construction at the dam site include sedimentation and erosion from operating heavy equipment along bank slopes; potential resuspension of river sediments caused by heavy equipment near the river; and erosion of exposed sites during storms. Other potential impacts include spillage of petroleum products, and incidental spillage of construction materials, such as cement and gravel. Construction activities often result in increased concentrations of dissolved calcium, sulfate, and chloride; increased concentrations of total iron and manganese; and

increased levels of turbidity, suspended sediments, and dissolved solids (Shields and Sanders 1986; Thackston and Snead 1982; and Canter 1977).

(2) Natomas. Construction could result in short-term increases in sediment loads in existing and future agricultural drainage. The exact amount is uncertain. Construction during the dry season when flows are low would serve to avoid impacts influenced by rainfall.

b. Current Patterns and Circulation (Current patterns and low, velocity, stratification, hydrologic regime):

(1) Upper American River. During construction, water would continue to flow through the existing diversion tunnel constructed for the uncompleted multi-purpose Auburn Dam. Upon completion of the flood control dam, flows would be diverted the two lower sluices in the dam, which would approximate the location of the former natural channel. Below the dam, flows would continue in the natural channel into Folsom Reservoir. During flood operations, the dam would regulate inflows from the North and Middle Forks into Folsom Reservoir to a maximum of approximately 86,000 cfs. It is important to note that the sluices are designed to remain open during flood operations. The sluice gates would only be closed in the event of potential failure of Folsom Reservoir or the lower American River levee system. The flood control dam would not affect water level fluctuations during non-flooding operations. During floods, the dam is designed to temporarily detain flows which would raise water surface elevations to a maximum height of 869 feet MSL. When the proposed dam is constructed, the existing diversion tunnel would be sealed to divert channel flows back to the main channel area. The dam is designed to detain flows only during flood events. Under non-flood conditions, water would flow unimpeded through the sluices.

(2) Natomas. After construction of new levees and raising of the existing levees, the waterways should return to pre-project conditions during non-flood periods. The fill material will not affect normal water circulation patterns since the material would be placed on the existing berm above normal water levels. The only time water would be on the fill material is during flood events. The pump station includes low flow sluices to convey non-flood flows in an unimpeded manner. However, as noted above, levee improvements would raise water surfaces elevations in the NEMDC and in lower Dry and Arcade Creeks during floods as a result of backwater effects.

Some of the water from the Pleasant Grove Creek would be temporarily stored in a detention basin located in the northeast portion of the Natomas basin. Flows from the Pleasant Grove Creek area would be diverted into the Pleasant Grove Creek Canal. Some of this flow would be diverted northward into the NCC for eventual discharge into the Sacramento River, and some would be diverted southward to the NEMDC for eventual discharge into the American River. During flood operations, the pump station would pump water from the NEMDC channel north of the Dry Creek confluence into the NEMDC channel south of the confluence. The pump station gates would retain waters in the southerly portion of the NEMDC channel until flood conditions subside.

c. Normal Water Level Fluctuations:

(1) Upper American River. During flood flows, the channel would continue to retain flood waters behind the dam. This is an intended operational objective of the project. Downstream areas which were recently remapped within the flood plain as a result of revised hydrologic projections following the 1986 storms would be returned to non-flood plain status.

(2) Natomas. The aim of the flood control project is to confine flood flows within the existing canal system and the pre-1986 flood plain. Consequently, water surface elevations within these canals and flood plains would be higher and flow velocities greater than if the project was not undertaken. Future development in the Natomas area would increase the amount of surface run-off and/or leaching of undesirable wastes. These issues are detailed in Chapters 5 and 6 of the EIS/EIR.

From a technical standpoint, the work in the Natomas area would remove most of the Natomas basin from the 100-year flood plain. This area was designated as a flood plain based on revised hydrologic calculations made after the 1986 storms. However, the area has not served to retain natural high waters or flood waters since the basin was reclaimed for agricultural purposes at the turn of the century. The new levee construction along Dry Creek and Arcade Creek is intended to mitigate for higher water surface elevations caused by the raising of levees in the Natomas area. The proposed levee improvements would serve to confine the increased water within existing flood plains. In accomplishing this objective, a small area north of Dry Creek and immediately east of the NEMDC would be removed from the flood plain due to the construction of a new levee along the north bank of Dry Creek.

d. Salinity Gradients NA (Because the American River system is a freshwater system, no salinity impacts would occur.)

e. Actions that will be taken to minimize impacts: (Also see 3.d. below.)

(1) Upper American River. To minimize direct impacts from sedimentation and incidental spillage, temporary measures would be implemented to divert natural streamflows from the active construction and storage sites. One such measure at the proposed dam site would be accomplished by utilizing the existing diversion tunnel that USBR had constructed at RM 20.1. Certain construction

activities would be limited to annual low-flow periods. Lastly, preparation of a Spill Prevention and Counter Measure Plan would partially mitigate inadvertent spills or releases.

(2) Natomas. In general, levee construction activities would be limited to annual low flow periods (generally 1 April to 1 November). Most of the levee work will be accomplished in areas above water. Standard contracting provisions for slope stabilization for levee work would reduce the potential for turbidity problems from levee bank erosion due to soil disturbance caused by vegetation removal and operation of heavy equipment.

3. **Suspended Particulate/Turbidity Determinations**:

a. Expected changes in suspended particulates and turbidity levels in vicinity of disposal/fill site:

(1) Upper American River. Foundation excavation, dredging operations, rock crushing operations, placement of embankment fill, haul road construction, and other general construction practices could result in temporary increases in suspended sediments and turbidity at the construction site.

Studies conducted by the U.S. Soil Conservation Service (1982) at construction sites in Placer and Sutter Counties reported erosion rates between 1 and 128 tons of material/acre/year. Based on the maximum erosion rate and a 3-year construction period, the construction of the dam and ancillary facilities could result in the erosion of 38,400 tons of material.

During flood conditions after completion of the project water surface elevations would rise behind the dam and saturate soils in the North and Middle Fork canyons. The amount of erosion resulting from periodic inundation would be influenced by the stability of the soils. Based on soil survey maps of the area (U.S. Soil Conservation Service 1979), the stability of the 10 principal soil associations in the canyons vary from moderately erodible to very highly erodible. Therefore, it is expected that during major floods some slope movement is likely with a fraction of this material eventually reaching the river channel. Further, during high flow events, some channel erosion would occur. Such actions presently occur during high flow events. Reliable data and analytical techniques to precisely predict increases or decreases in sediment loads and turbidity attributable to operation of the flood control dam are not available.

(2) Natomas. Levee work would be conducted during dry periods to minimize the potential for increases in turbidity. Construction of the pump station would require some work in the waterway; however, use of watertight forms and other management practices would minimize the potential for increased turbidity levels.

b. Effects on chemical and physical properties of the water column: (Also see 3.a. above and 4. below.)

(1) Upper American River. Generally, construction activities will occur in the dry with water flows diverted from the in-stream construction areas. Suspended sediment and turbidity effects on chemical and physical properties of water are expected to be minimal.

(2) Natomas. Since most of the levee work will be performed during low flow periods and above water, turbidity and suspended sediment effects on the chemical and physical characteristics of the water column will be insignificant.

c. Effects on biota - See 5.b., c., and d. below.

d. Actions taken to minimize impacts:

(1) Upper American River. To minimize erosion impacts on receiving waters, temporary water quality control measures would be implemented to contain and sequester spills and sediment. These measures include diversion of stream flows from active construction sites and construction of a network of temporary interceptor dikes and ditches at construction sites to convey sediment-laden flows into temporary settling basins. The sediment basins would retain water for sufficient time to allow suspended sediments to settle from the water column (Anton and Bunnell 1976; Koehn and Rispoli 1982). In addition, certain construction activities would be limited to annual low flow periods (USEPA 1973). Effluent from the sediment basins will be monitored for selected water quality parameters (pH, DO, turbidity) during construction (W. Pierson, pers. comm. 1989).

The discharge of material for the construction of the dam would be conducted in a dewatered area and within watertight forms. Consequently, no increase in either suspended sediments or turbidity is expected.

Flood-related erosion and slope failure could be a problem in the inundation zone. Canyon inundation would be an infrequent event. However, during the life of the project, sloughing could occur over a significant portion of the inundation zone. Whether or not the impact of this sloughing would be greater or less than under without-project conditions during similar rare storm events is not known. In the event, suspended materials would be transported downstream to Folsom Reservoir where increased retention times would permit settling of materials prior to entry into the lower American River.

(2) Natomas. Construction scheduling, use of watertight concrete forms, and other construction management practices would reduce turbidity levels.

4. **Contaminant Determination**: (Also see 6.b. below.)

a. Upper American River. Because the aggregate material to be used to construct the dam will be obtained from an existing quarry no contaminants will be introduced into the aquatic environment.

Historically, water quality parameters for the upper American River have been well within acceptable limits to achieve water quality objectives and beneficial uses mandated by Central review of the California Environmental Response, Compensation, and Liability Information System (CERCLIS) maintained by the U.S. Environmental Protection Agency, and the Hazardous Waste And/Or Substance List maintained by the California Office of Planning and Research did not identify any hazardous and/or toxic waste sites within the inundation zone of the flood control dam (see Chapter 5 in the EIS/EIR). Further, water quality studies reviewed by Shulters (1982) in the North and Middle Forks of the American River did not record any contaminant violations (see Chapter 6 in the EIS/EIR).

During construction activities, the possibility of fuel and/or chemical spills exists. However, the use of interceptor dikes and ditches and temporary settling basins would minimize or eliminate the entry of spills into receiving waters.

b. Natomas. Fill material used for levee construction would be obtained from a borrow area certified as being free from contaminants.

5. **Aquatic Ecosystem and Organism Determinations**:

a. Effects on plankton See food web effects in d. below.

b. Effects on biota: (Also see food web effects in d. below.)

(1) Upper American River. No direct impacts to fisheries are anticipated.

(2) Natomas. Levee raising would not affect the channel bottom because the placement of fill material would be on the top of existing levees above the ordinary high water mark. Construction of new levees would be performed during dry periods when aquatic organisms would not be inhabiting the sites. Construction in the Natomas area would result in the temporary displacement of wildlife in construction areas. However, because the duration of construction is estimated to be 2 years, no long-term disruption of the food chain or decrease in the diversity of plant and/or animal species is anticipated.

c. Effects on nekton:

(1) Upper American River. Past surveys (1930's) conducted by the Department of Fish and Game prior to completion of Folsom Dam reported six species of fish occupying the North Fork, including Sacramento sucker, Sacramento squawfish, rainbow trout, hardhead, chinook salmon, and brown trout and estimated densities at 100 trout per mile (USFWS 1991). Existing movement of animals, especially into and out of feeding, spawning, breeding, and nursery areas should not be impeded by the flood control dam since the outlet works on the dam would remain open to convey virtually the same volume of flows as the existing diversion tunnel.

(2) Natomas. There is likely to be a temporary disruption into and out of potential breeding, spawning, feeding, and nursery areas in the NEMDC above its confluence with Dry Creek during construction of the pump station. Upon completion, movements would be accommodated through sluices.

d. Effects on aquatic food web:

(1) Upper American River. The discharge of material associated with dam construction would permanently destroy all aquatic organisms within the footprint of the dam. This would not result in a significant loss based on the very limited zone of impact and the disturbed character of the site.

(2) Natomas. Approximately one acre of 404 jurisdictional wetland and approximately 423 acres of upland habitat (grasslands, fallow fields, levee rights-of-way, and agricultural field) would be lost by construction activities associated with the levee improvements in the Natomas basin. No significant disruption of the food chain or the diversity of plant or animal species is anticipated.

Additional adverse impacts to jurisdictional wetlands from local development following project completion will be avoided or mitigated through the Department of the Army's permit program which regulates activities subject to filling wetlands pursuant to Section 404 of the Act. Similar impacts to non-jurisdictional wetlands will be avoided or mitigated through the program being developed by local governments in consultation with the California Department of Fish and Game under the State endangered species law.

e. Effects on special aquatic sites:

(1) Sanctuaries and refuges NA

(2) Wetlands:

(a) Upper American River. The dam construction and quarry activities are unlikely to impact wetlands subject to the jurisdiction of Section 404 of the Clean Water Act. (See discussion under food web in d. above. Also see Chapter 7 of the EIS/EIR.)

(b) Natomas. One acre will be impacted by the construction. (See discussion under food web in d. above. Also see Chapter 7 of the EIS/EIR.)

(3) Mudflats NA

(4) Vegetated shallows NA

(5) Coral reefs NA

(6) Riffle and pool complexes The work requires direct access or proximity to water resources in order to accomplish the project purpose. The one acre site required for construction of the pump station in the Natomas area is the smallest site practicable to accomplish the goal of controlling flows through NEMDC during flood events to Natomas Area.

f. Threatened and endangered species:

(1) Upper American River. There are several thousand elderberry shrubs in the inundation area. To mitigate for these potential impacts to valley elderberry longhorn beetle, 2,700 acres of land will be acquired adjacent to the lands to be obtained for general fish and wildlife mitigation. This area will be planted with 32,336 elderberry shrubs mixed with other native species. Formal consultation with the Fish and Wildlife Service has been completed and their Biological Opinion confirmed that this mitigation plan is sufficient to avoid jeopardizing the continued existence of the threatened valley elderberry longhorn beetle which may inhabit the affected shrubs. There are no other known endangered species recorded within the proposed quarry area or at the proposed dam site (See Chapter 8 in the EIS/EIR for a more detailed discussion). Therefore, the discharge will not jeopardize the existence or modify habitat of a threatened or endangered species.

(2) Natomas. No Federally listed species would be directly impacted by the levee construction. Locally approved development following project completion would likely result in adverse affect to habitat (indirect impacts) of the Federally threatened valley elderberry longhorn beetle. However, suitable avoidance and/or mitigation will be accomplished which will avoid jeopardy. Two State-listed species, the Swainson's Hawk and the giant garter snake are found in the Natomas area. A series of avoidance and mitigation measures will be implemented by the local sponsor in consultation with the California Department of Fish and Game in compliance with the California Endangered Species Act to assure impacts to the species would not jeopardize their continued existence. Chapter 8 in the EIS/EIR discusses several mitigation measures that will be undertaken to minimize effects.

g. Other wildlife NA

h. Actions taken to minimize impacts:

(1) Upper American River. All work would be confined to the smallest area possible. Unavoidable habitat losses would be mitigated through the development of the mitigation/management plan. (See Chapter 7 of the EIS/EIR.)

(2) Natomas. All work would be confined to the smallest area practicable. Unavoidable wetland losses would be mitigated through the development of new wetlands. (See Chapters 7 and 8 of the EIS/EIR.)

6. **Proposed Fill Site Determinations**:

a. Mixing zone determination NA

b. Determination of compliance with applicable water quality standards:

(1) Upper American River. Violation of water quality and/or effluent standards is not anticipated. Temporary storage of water behind the dam (<20 days max.) is not sufficient to anticipate any depletion of dissolved oxygen, any temperature stratification, nutrient increase or corresponding eutrophication. Because of the inert characteristics of construction materials (concrete, steel, etc.), flows through the dam, either during flood or non-flood conditions, are not expected to adversely impact the chemistry, clarity, color, odor, or taste of the water.

(2) Natomas. No water quality or effluent standards would be violated either during or after the construction period.

c. Potential effects on human use characteristic:

(1) municipal and private water supply Only two known intake structures have been identified. One, located upstream of the proposed dam site, is used periodically by the Placer County Water Agency as needed. Construction at the dam site will avoid this intake. The second intake is located in the lower American River where no construction will occur.

(2) recreational/commercial fisheries and water related recreation:

(a) Upper American River. During construction operations, recreational values would be significantly affected in and around the dam site. Presently this area is used principally for day use recreation, including swimming, non-whitewater rafting (floating), off-road vehicles, picnicking, nature study, and hiking. The principal whitewater rafting reaches are located above the dam site on the Middle Fork and would be largely unaffected by construction. The principal whitewater rafting reaches on the North Fork are located above North Fork Dam and would also be unaffected by construction.

Long-term impacts on recreation in the canyon area could result from a reduction in road and trail access to the area. This would be the case if the present alignment of Highway 49 is not maintained for local access purposes, then use of the canyon area could suffer significantly, or if major roads and trails which traverse the inundation zone are eroded and left unrepaired, recreational opportunities will be diminished accordingly. These potential impacts are discussed in Chapter 14 of the EIS/EIR.

(b) Natomas. Provision for a bicycle trail concurrent with levee construction would increase recreational opportunities.

(4) Aesthetics. Aesthetic values would be adversely affected during construction operations. Visual impacts are detailed in Chapter 16 of the EIS/EIR. Upon completion of construction activities, the 425-foot-high dam would significantly dominate the viewshed from selected vistas. Degradation of aesthetic values is also anticipated due to conversion of agricultural and open space lands to urban development. Increased levels of flood protection provided by the project would increase property values in the Natomas area.

(5) Parks, National and Historical monuments, National seashores, wilderness areas, research sites, and similar preserves. NA

7. **Determination of Cumulative Effects on the Aquatic Ecosystem**:

a. Upper American River. Cumulative effects on the aquatic ecosystem from future discharges of fill are expected to be insignificant in the area of the flood control project because all lands will be publicly held and no development will occur. It is possible that recreation facilities or public works projects, such as construction of water intakes, could occur in the future.

b. Natomas. Cumulative effects on the aquatic ecosystem from future discharges of fill material for levee construction are not expected to be significant since areas waterward of the levees would remain undeveloped. Certain public works facilities, such as drain outlets, may be constructed in the levees in the future; however, plans for such projects, other than those discussed in the Cumulative Impacts chapter, are not known.

8. **Determination of Secondary Effects on the Aquatic Ecosystem**:

a. Upper American River. Periodic inundation ranging from several miles every 2 to 3 years up to about 40 miles for the

200-year event of stream habitat in the Middle and North Fork American Rivers will occur over relatively short duration (up to about 20 days near base of dam). This is an intended operational objective of the proposed project. Short-term inundation impacts are not expected to be significant. Dam operations could cause additional sedimentation and sloughing during floods. Inundation periods would be longest immediately behind the dam and would diminish in duration as inundation extends up the canyon. Based on an inundation analysis, it was determined that about 1,200 acres of various canyon habitat types could potentially be lost during the 100-year period of analysis. (A detailed inundation analysis is included in Appendix Q.)

Best management practices required by the approving or implementing agency will be applied in connection with any structures, such as recreation access areas, raft take-out's and put-in's, campgrounds, water intakes, which are approved and constructed in the future.

It is likely that construction of a flood control dam would require in-kind, in-place replacement of the existing Highway 49 out of the North Fork canyon via an elevated bridge. No growth-inducing impacts are expected as a result of the proposed in-kind replacement.

b. Natomas. Under all alternatives, the Natomas basin would be sufficiently protected to allow development to proceed in accordance with the flood plain management regulations imposed under the National Flood Insurance Program. Future development in the Natomas area would increase the amount of surface run-off and/or leaching of undesirable wastes. These issues are detailed in Chapters 5 and 6 of the EIS/EIR. Best management practices to control urban run-off should be applied in connection with any subsequent development in any areas removed from the flood plain as a result of the project.

PART 4 FINDINGS OF COMPLIANCE FOR 200-YEAR FLOOD PROTECTION

1. No significant adaptation of the guidelines were made relative to this evaluation.

2. Six alternative flood protection plans, all involving fill except for the 100-year storage alternative, were evaluated for this project. (See Table V-17 in the Main Report for a detailed summary comparison of the plans.) The 400-year flood protection plan is the least environmentally damaging practicable alternative in the following comparison to the six alternatives. The impacts resulting from the 200-year alternative are very similar to those of the 400-year alternative, resulting in less direct construction impacts, and potentially slightly greater impacts from inundation and sloughing.

a. The 400-year level flood protection plan would consist of a higher dam (additional 75 feet) and increased size (additional 350,000 acre-feet storage) than the selected 200-year level of flood protection. Although a larger project than the selected 200-year flood protection plan, the operational impacts of the larger dam would be smaller. The higher cost of the 400-year protection (approximately $96 M more in first cost) was not supported by the local sponsor.

b. The 150-year level of flood protection would result in impacts to the lower American River and to the Folsom Reservoir area. Although the project would have a lower level of flood protection than the selected plan, significant effects to aquatic resources including riparian vegetation and salmon would occur. In addition, this plan would result in increased exposure of impacts to cultural resources at Folsom Dam.

c. The 100-year flood protection/storage plan involves the permanent reoperation of Folsom Reservoir. Although there is no fill associated with this plan, reduced flows in the lower American River will have major adverse effects on riparian habitat and salmon from increased flood control storage at Folsom Reservoir.

d. The 100-year flood protection/levee plan would involve similar levee construction impacts as for the 150-year level flood protection plan. Although there would be no increased flood control storage, major adverse effects on riparian habitat and salmon are anticipated from reoperation of Folsom Reservoir.

e. The 100-year flood protection levee/storage/spillway plan would also have construction impacts similar to the 150-year level protection, long-term losses to aquatic resources (including riparian habitat and salmon fishery) resulting from the combination of increased storage and releases at Folsom Reservoir.

3. The planned fill of 5 million cubic yards on the North Fork American River near the City of Auburn in Placer County (200-year flood protection) would not violate any applicable State water quality standards. The discharge of fill will not violate the Toxic Effluent Standards of Section 307 of the Clean Water Act.

4. Use of the selected site for the recommended 200-year level flood protection will not harm any endangered species or their critical habitat.

5. The proposed placement of fill will not result in significant adverse effects on human health and welfare, including municipal and private water supplies, recreation and commercial fishing, plankton, fish, shellfish, wildlife, and special aquatic sites. The life stages of aquatic life and other wildlife will not be adversely affected. Significant adverse effects on aquatic ecosystem diversity, productivity and stability, and recreational,

aesthetic and economic values will not occur. Short-term adverse effects on the aquatic ecosystem are unavoidable, but will be minimized by the construction management practices or will be offset by appropriate mitigation measures.

6. Appropriate steps to minimize potential adverse impacts of the discharge on aquatic systems include: dewatering of the Upper American River project site during construction to minimize contact between fill material and the North Fork of the American River; situating the discharge site, i.e., the dam site, to minimize the size necessary to prosecute the work consistent with the goals of the flood control project; placing fill material directly into waters of the U.S., specifically for the construction of the pump station on NEMDC, within watertight forms thereby eliminating contact with canal flows; placing fill material for the enlargement of levees on the landward side in the Natomas area to restrict contact with stream flows; material placement on the waterward side of levees, particularly for construction of new levees on Dry and Arcade Creek, to be performed during periods of low flow to minimize contact with stream flows.

7. On the basis of the guidelines the proposed sites for the discharge of fill are specified as complying with the inclusion of appropriate and practical conditions to minimize pollution or adverse effects to the aquatic ecosystem.

REFERENCES

Anton, W.F. and J.L. Bunnell. 1976. Environmental Protection Guidelines for Construction Projects. Journal of the American Water Works Association 68 (12): 643-646.

Barbour, M.G. and J. Major. 1988. Terrestrial Vegetation of California. California Native Plant Society Special

-Part 3

Publication No. 9. Sacramento, CA.

Bechtel International, Inc. 1985. Final Report on the Evaluation of the Auburn Dam Project. Consultants Report to the California Department of Water Resources.

Collins, B. and T. Dunne. 1990. Fluvial Geomorphology and River-Gravel Mining: A Guide for Planners, Case Studies Included. Special Publication No. 98. California Department of Conservation, Division of Mines and Geology. Sacramento, CA.

Dunne, T. and L.B. Leopold. 1978. Water in Environmental Planning. W.H. Freeman and Company, San Francisco, CA.

Koehn, E. and J.A. Rispoli. 1982. Protecting the Environment During Construction. Journal of the Construction Division (ASCE) 108(CO2): 233-246.

Madej, M. A. 1990. Determining Replenishment Rates For Aggregate Mining. In: J. Waldvogel, ed. Proceedings of the 8th Annual California Salmon, Steelhead, and Trout Restoration Conference. Eureka, CA.

Shulters, M.V. 1982. Water Quality Assessment of the American River, California. U.S. Geological Survey. Sacramento, CA.

Smith, Felix. 1977. A Short Review of the Status of Riparian Forests in California. In: Riparian Forests in California -- Their Ecology and Conservation. A. Sands, ed. A symposium sponsored by Institute of Ecology, University of California, Davis, CA., and Davis Audubon Society.

U.S. Army Corps of Engineers. 1990. American River Watershed Investigation, California. Appendix M, Chapter 7: Reservoir Rim and Slope Stability Study. Geotechnical Branch, Sacramento District. Sacramento, CA.

U.S. Water and Power Resources Service. 1980. Auburn Dam -- Seismicity and Dam Safety. Supplement No. 2 to the Final Environmental Statement, as Supplemented and Amended.

U.S. Environmental Protection Agency. 1973. Processes, Procedures, and Methods to Control Pollution Resulting From All Construction Activities. EPA 430/9-73-007. Office of Air and Water Programs. Washington, D.C.

U.S. Fish and Wildlife Service. 1991. American River Watershed Investigation - Substantiation Report: Auburn Area Volume II. Ecological Service Office, Sacramento Field Office. Sacramento, CA.

U.S. Soil Conservation Service, U.S. Forest Service, and Economic Research Service. 1982. Sutter-Placer Watershed Area Study. Prepared by Yuba City Field Office, Auburn Field Office, and USDA River Basin Planning Staff, Davis, CA.

Personal Communications

Pierson, Wayne. Central Valley Regional Water Quality Control Board. August 1989.

American River Watershed Investigation, California

APPENDIX H

Recreation

AMERICAN RIVER WATERSHED INVESTIGATION, CALIFORNIA
FEASIBILITY REPORT

APPENDIX H

RECREATION RESOURCES APPENDIX

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RECREATION RESOURCES APPENDIX

CHAPTER I - INTRODUCTION

This appendix describes the existing recreation facilities and identifies the recreation opportunities and needs present within the study area. The coordination efforts undertaken to formulate a recreation increment of the tentatively selected plan are also described along with a detailed description of the proposed recreation facilities that are included in the alternative flood control plans. Included in the description is an explanation of costs and benefits associated with the proposed recreation features. Finally this appendix provides an analysis of the impacts of the reoperation of Folsom Dam and Reservoir on the recreation resources in the Folsom State Recreation Area and the Lower American River.

CHAPTER II - BASELINE/EXISTING CONDITIONS

1. Natomas. - Natomas consists mostly of farmlands, and former farmlands, which have been converted to urban development. There was little public recreation development within the area prior to the conversion of some areas to urban uses. Privately owned farmlands, especially rice fields and drainage channels, have historically been used for bird hunting and more recently for bird watching. Landowners often lease the hunting rights on their farmlands to hunting clubs.

Bordering the west side of Natomas is the Sacramento River, a recreation resource of State and regional importance. Although the vast majority of the lands along the river are privately owned, the river itself is heavily used for fishing (from both banks and boats), waterskiing, cruising, jet skiing, and to a lesser extent for flat-water canoeing and kayaking. On summer weekends, the river is very crowded often seeming as though it were gunwale to gunwale in boats. Public access to the river is provided at various riverfront public parks and private marinas. Public launching ramps in Natomas are located at Discovery Park near the confluence with the American River, and at Elkhorn (adjacent to the I-5 bridge).

On the southern edge of Natomas is the American River Parkway and Discovery Park. Discovery Park is managed by the Sacramento County Department of Parks and Recreation. It is approximately 150 acres in size and provides developed lawns, picnic sites, an archery range, a boat launching ramp, swimming beaches, and support facilities such as parking, shelters, barbeques, restrooms and drinking water fountains. East of Discovery Park, Sacramento County's American River Parkway extends 23 miles upstream to the Folsom State Recreation Area which begins at Nimbus Dam.

Along the eastern edge of Natomas is the Natomas East Main Drainage Canal (NEMDC), which is the former channel of Dry Creek straightened and confined by 20 to 30-foot high levees. Bordering the east bank/levee of the NEMDC is the Union Pacific Railroads' mainline. Presently, the NEMDC has no existing developed public access or recreation facilities, except for a 0.6 mile segment of the Sacramento Northern bicycle/pedestrian trail along the east levee near its mouth. However, some low levels of recreation use do occur in the NEMDC area. This primarily consists of children and teenagers from adjacent neighborhoods riding BMX bicycles, and "hanging-out." Adults and neighborhood children are regularly observed fishing in the NEMDC and its tributary streams. Illegal off-road vehicle use (4-wheel drive vehicles and motorcycles), unauthorized camping by transients and homeless people, and illegal dumping of trash and refuse has been observed on the levees and in the channel areas. The lack of defined public access, the illegal activities, and the trash strewn landscape serves to deter additional public use of the NEMDC.

Within urbanized South Natomas, the existing recreation resources consist of neighborhood parks, community parks, and city parkways. Because much of South Natomas was urbanized prior to the 1981 establishment of a Quimby ordinance, allowing the assessment of new growth for additional local services such as parks, new park development did not keep pace with the residential development. Thus there is a significant backlog of park development required to meet the minimum standards established by the South Natomas Community Plan. These new parks and recreation facilities will have to be financed out of general city operating funds or local assessment districts. The South Natomas community plan calls for the development of additional recreation lands and facilities to meet the following standards:

- Neighborhood parks would be developed at a rate of 2.5 acres per 1,000 residents, and would be located within a half mile radius of residents. Neighborhood parks are often situated adjacent to elementary schools, their size is generally two to 10 acres. Facilities may include landscaping, a tot lot, children's play structures, and an unlighted sports field or court.

- Community parks would also be developed at a rate of 2.5 acres per 1,000 residents, and would be located within a three-mile radius of major concentrations of residents. They may range in size from six to 60 acres. In addition to neighborhood parks elements, they might have restrooms, large landscaped areas, a community center, swimming pool, lighted sports fields, and specialized equipment.

- City parkways are linear parks or closely interconnected systems of city or school parks which would be developed along a roadway, waterway, bikeway, or other common corridor. City parkways are a type of community park.

To date, South Natomas of the City of Sacramento has 84 acres of developed parks (see Table H-1 and Figure H-1); another 97 acres of designated park sites have yet to be acquired. The remaining 120 acres of designated park sites have been acquired, but are undeveloped.

The South Natomas Community Plan also calls for developing a system of on-street bicycle routes for commuters and attractive off-street bicycle paths for recreational use. To date, the only off-street bicycle path which has been developed in the area is

Table H-1

Existing and Proposed Natomas Parks

Map Key #	Park Name or Location	Acres
1	Gateway Park*	5.0
2	Gateway School Park*	5.0
3	Willow Creek School*	10.0
4	Orchard Park Site*	15.0
5	Main Canal Parkway*	16.5
6	East Natomas Park*	10.5
7	Natomas Oaks Park*	12.5
8	Bannon Creek Parkway**	26.4
9	Creekside Park*	6.0
10	Bannon Creek School Park*	5.0
11	High School Park*	10.0
12	Jefferson School Park*	5.0
13	South Natomas Park*	6.0
14	Oakbrook Park*	2.0
15	Oakbrook Park Extension*	2.0
16	American Lakes School Park*	7.0
17	Northgate Park	17.0
18	Fong Ranch Park Site*	30.0
19	Meister School Park Site*	4.0
20	Bridgeford Park*	1.6
21	Sutter Business Center Park*	27.0
22	Garden Valley School Park*	2.9
23	Rio Tierra School Park*	10.0
24	Straugh School Park*	3.0
25	Straugh School Extension*	3.0
26	Ninos Parkway*	28.3
27	Ninos Park	3.8
28	Discovery Park (City Portion)	20.0
29	Gardenland Park	6.0
	Total Acreage	300.5

* Undeveloped park sites/lands.
** Partially developed park sites.

Sacramento County's Jedediah Smith Trail in the American River Parkway. The major proposed off-street bikeways are shown on Figure H-2 and listed below:

- Bannon Slough from San Juan Road to Discovery Park.

- East Levee Road from I-80 to Garden Highway.

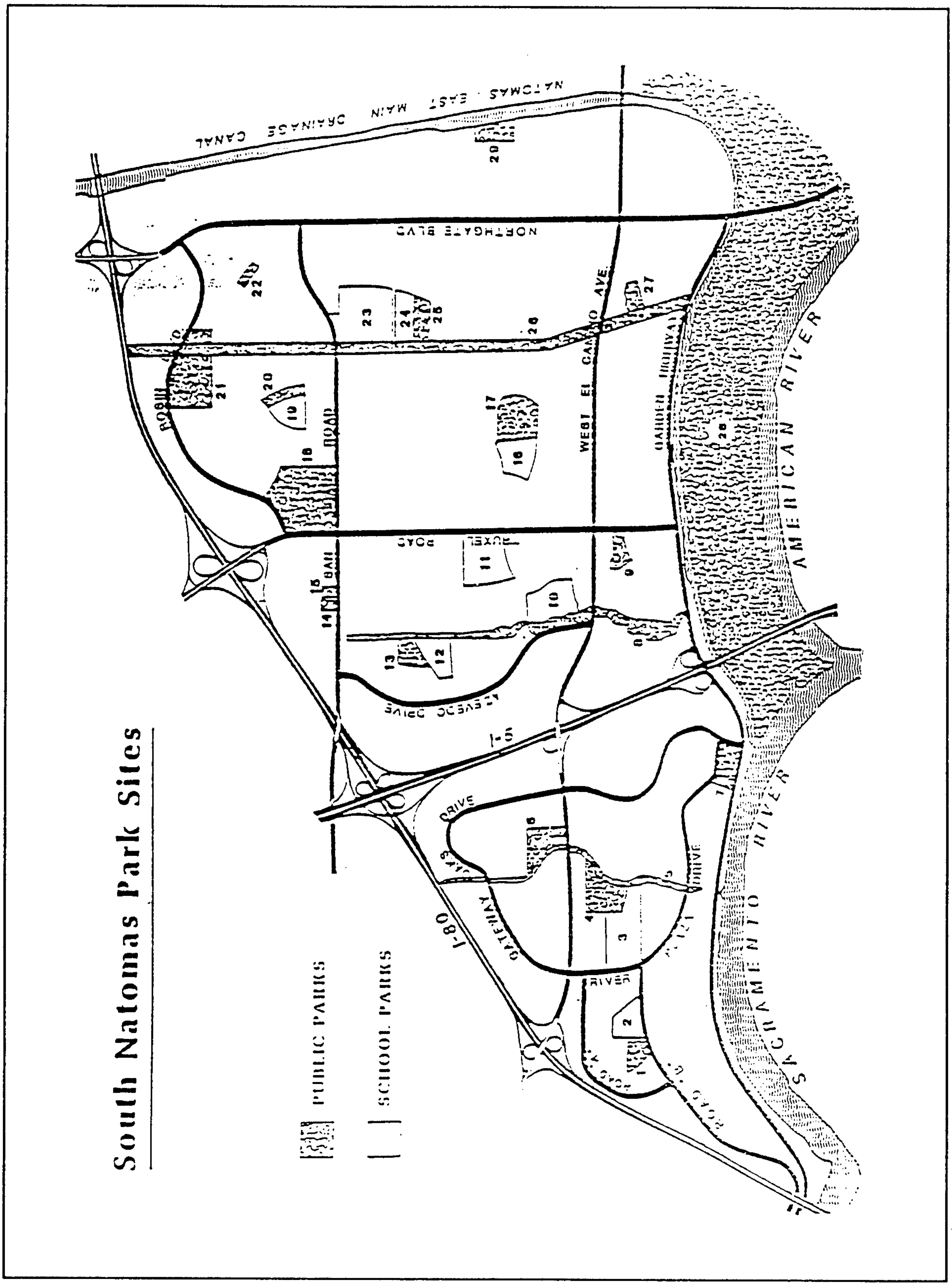

South Natomas Park Sites
PUBLIC PARKS
SCHOOL PARKS
NATOMAS EAST MAIN DRAINAGE CANAL
NORTHGATE BLVD
WEST EL CAMINO AVE.
AMERICAN RIVER
SACRAMENTO RIVER
I-80
I-5
ACEVEDO DRIVE
GATEWAY
RIVER
DRIVE
ROAD

Figure H-1

Existing and Proposed South Natomas Bikeways

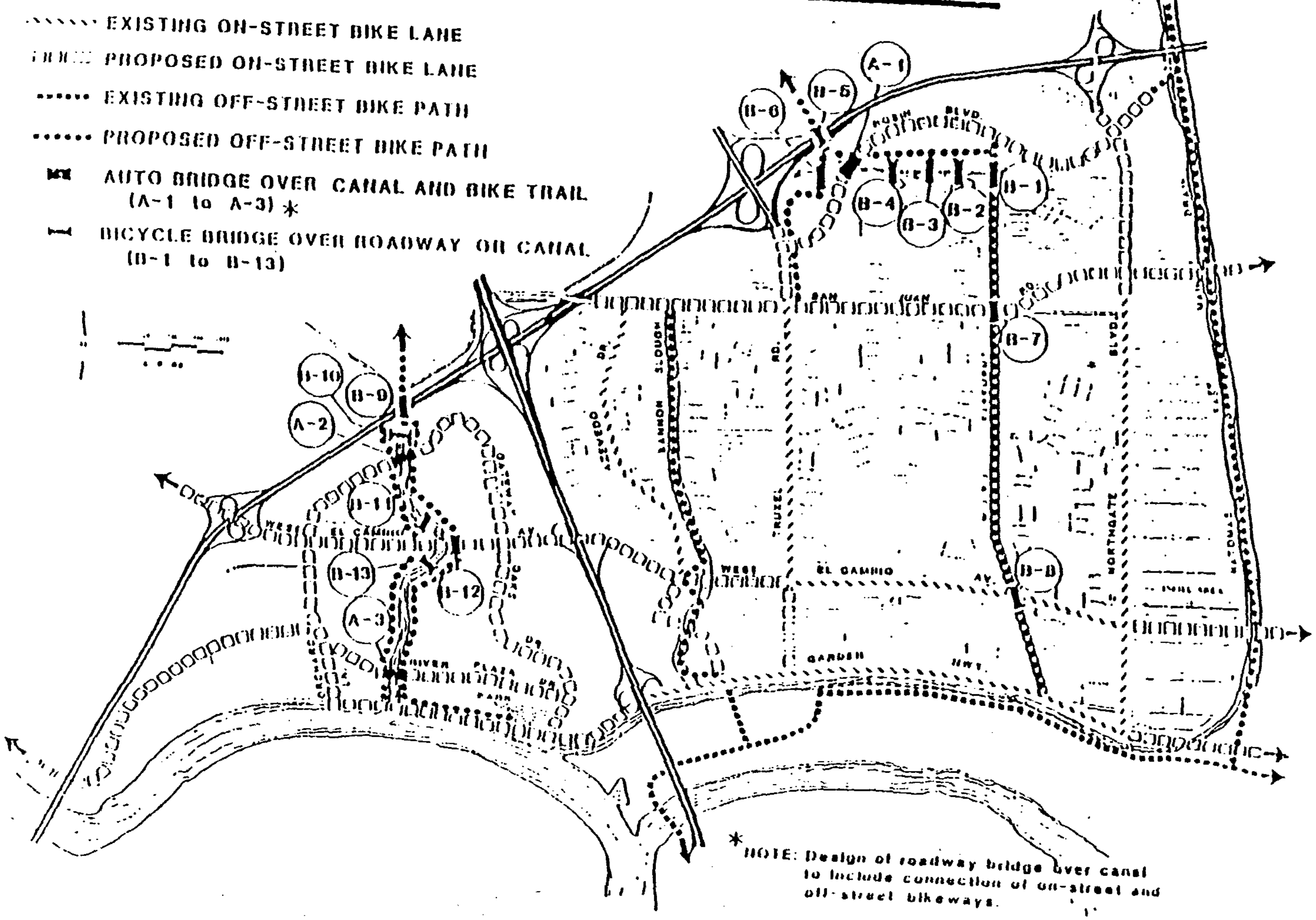


Figure H-2

- NEMDC from I-80 to Garden Highway.

- Power line right-of-way from Rosin Boulevard to Garden Highway.

- East-West connection from power line right-of-way to Truxel Road.

2. Lower Dry and Arcade Creeks. - These two creeks drain nearly all of North Sacramento and portions of Southern Placer County into the NEMDC. Arcade Creek has been confined within 5 to 20-foot high levees west of Marysville Boulevard. No Public access has been developed though Haggenwood Park which abuts the creek. The Sacramento Northern recreation trail crosses the creek west of Rio Linda Boulevard. The city's trail master plan calls for the eventual development of a paved foot and bicycle trail along Arcade Creek.

Dry Creek flows from southern Placer County (Roseville and Newcastle area) through the rural-residential Rio Linda area into the NEMDC. The creek has several channels and except for the area at the confluence with the NEMDC has not been confined by the construction of levees. No public access has been developed along Dry Creek although the City of Sacramento has purchased 250 acres of the Hansen Ranch property at the NEMDC confluence for a future golf course and athletic field development. Approximately eight miles upstream of the NEMDC confluence, Sacramento County has developed the Gibson Ranch Regional Park and has developed a golf course at Cherry Island. The county's Open Space Master Plan calls for the development of a parkway/open space corridor with a paved recreation trail along all of Dry Creek extending into Roseville, Placer County and eventually on to Folsom Reservoir. Thus a 50+ mile loop trail system would be created with the American River Parkway.

3. Lower American River. - The American River Parkway (see Figure H-3) includes a series of 14 connected parks, comprising approximately 5,000 acres, along the publicly owned lands of the lower American River. Much of the lower half of the parkway is bordered by 20 to 30-foot high earthen levees. The levees help to block out the sights and sounds of the surrounding urban development and activity. These physical barriers along with extensive stands of mature riparian forest give the parkway a "wilderness in the city" quality. One of the most popular features of the parkway is the 26-mile Jedediah Smith paved bicycle and pedestrian trail which extends from Discovery Park to Folsom Reservoir (the trail also connects with the Sacramento River Trail and Old Sacramento State Historic Park). The 23 miles of river below the Nimbus Dam has also been designated as a wild and scenic river under both the State and Federal programs. The American River Parkway which is managed by the Sacramento County Parks and Recreation Department, is widely recognized as

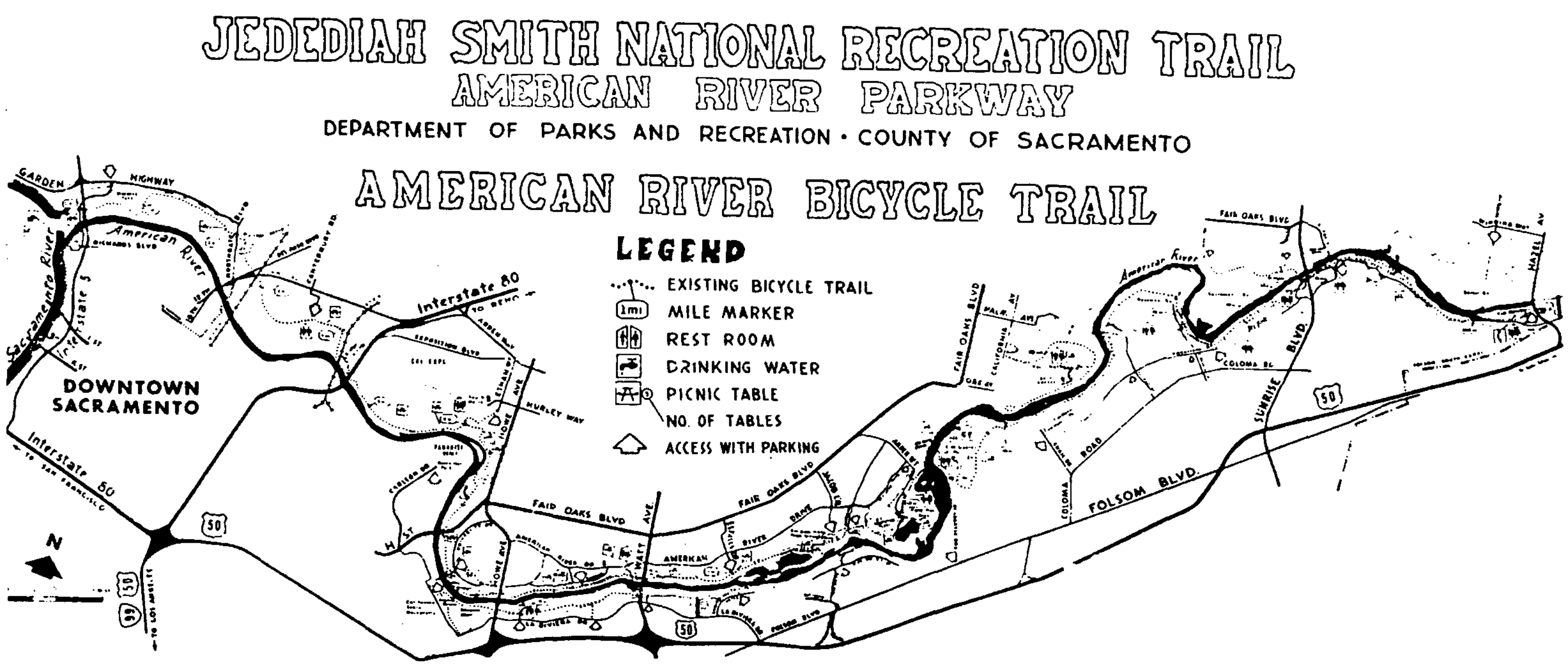

JEDEDIAH SMITH NATIONAL RECREATION TRAIL
AMERICAN RIVER PARKWAY
DEPARTMENT OF PARKS AND RECREATION • COUNTY OF SACRAMENTO
AMERICAN RIVER BICYCLE TRAIL
LEGEND
EXISTING BICYCLE TRAIL
1mi MILE MARKER
REST ROOM
DRINKING WATER
PICNIC TABLE
NO. OF TABLES
ACCESS WITH PARKING
DOWNTOWN SACRAMENTO
GARDEN HIGHWAY
American River
Sacramento River
Interstate 5
Interstate 80
FAIR OAKS BLVD
FOLSOM BLVD.
SUNRISE BLVD.
WATT AVE.
HURLEY WAY
COLOMA RD
50
99
N

Figure H-3

one of the Nation's premier urban parkways. The parkway provides excellent opportunities for recreation activities for approximately three-quarters of a million people that reside within a one-half hour commuting distance.

Sacramento County estimated the parkway use at 5.5 million visitors in 1988. Visitation is expected to increase to 7.5 million by 2000 and 9.6 million by 2020, assuming stable river flows are available (Hinton 1987). Based on a County of Sacramento survey (1983), approximately 32% of all visits were associated with water-dependent activities (e.g., swimming, boating, and fishing), and 53 percent were associated with water-enhanced activities (jogging, nature study, hiking, picnicking). Tables H-2 and H-3 show a breakdown of parkway use by activity and seasonal use. Entrance fees are charged on all automobile access roads during the late-spring, summer, and early fall peak use seasons.

Table H-2

American River Parkway Recreation Activity by Type

Activity	Percentage of Use
Sightseeing	15.8
Rafting	10.0
Fishing	9.5
Swimming	9.5
Relaxing	7.4
Biking	6.7
Picnicking	5.1
Other	36.0

Table H-3

Seasonal Use of American River Parkway

Season	Percentage of Use
01 Jan - 05 Mar	17.5
06 Mar - 09 Jun	26.3
10 Jun - 25 Sep	29.6
26 Sep - 31 Dec	26.6

The lower American River is a major site for recreational boating (rafting, kayaking, canoeing). It is estimated that boating accounts for approximately 662,000 user-days annually, and represents approximately 12 percent of the total recreation demand on the lower American River. The economic benefits associated with river boating have been estimated between $7.5 and $8.3 million annually (CSWRCB 1988).

River boating, particularly commercial rafting, is dependent primarily on three factors: air temperature, river flows, and season of the year. Temperature is the most significant factor attracting recreational rafting. Regardless of how good other conditions may be, when ambient temperatures are cold, even during the peak recreation season, rafting declines. Further, raft rentals are generally confined to the peak recreation season. Approximately 90 percent of the annual rental business occurs between Memorial Day and Labor Day, even though prime conditions may exist into October (David Hill, pers. comm. 1989). Finally, sufficient flows are necessary in the river to permit boating. Insufficient flows result in either unfloatable conditions, in which the boats or rafts drag the bottom requiring portage over shallow riffle areas, or prolonged travel times.

Swimming and wading are other popular water-dependent activities affected by river flows. Popular swimming areas include Sunrise Avenue Bridge area, El Mando Access area, San Juan Rapids, Ancil Hoffman/Rancho Cordova Park, the long pool between Sara Court and Goethe Park/Arden Bar Park Bicycle bridge, Gristmill/Harrington Way Access, Watt Avenue Bridge, Howe Avenue Bridge, Paradise Beach, and Tiscornia Park. However, only Paradise Beach and Tiscornia Park have beaches with extensive areas of sand (CSWRCB 1988).

Swimming and wading have been estimated to account for approximately 10 percent of the total recreation use in the American River Parkway, which corresponds to approximately 552,000 visits annually (based on 1985 visitation estimates). The annual value of this recreation has been estimated at between $7.4 and $17.1 million annually (CSWRCB 1988).

Trail use such as jogging, bicycling, hiking, and horseback riding represent the dominant intended use of the Parkway (Gold, 1986). The 26-mile Jedediah Smith paved trail meanders throughout the Parkway, passing through a wide variety of different habitat types along the river. Along much of the parkway there is a parallel un-paved equestrian trail. The constantly changing habitat types makes traveling the trail an aesthetically pleasing experience.

4. <u>Lake Natoma (Nimbus Dam)</u>. - Lake Natoma, which is formed

by Nimbus Dam, is the downstream end of the Folsom State Recreation Area (SRA), which also includes Folsom Lake. Nimbus Dam and the lake serve as an equalizing reservoir for the varying water releases from Folsom Dam. Thus Lake Natoma has very little water level fluctuation and has developed an attractive, natural appearing band of riparian vegetation around its shore. Lake Natoma is managed by the California Department of Parks and Recreation (DPR) as a less intense recreation area emphasizing non-motorized water recreation. Developed facilities include the California State University, Sacramento (CSUS) aquatic center which provides instruction and equipment rentals for rowing, boardsailing, canoeing, and small-boat sailing. The CSUS crew team and a private rowing club train on the lake and numerous national collegian rowing events have been held on the lake.

Other facilities at Lake Natoma include a picnic area and an eight mile segment of the American River paved bicycle and pedestrian trail which continues on to Folsom Lake. Bank fishing is common along the shoreline and swimming and diving occur from the rock outcrops at the upper end of the lake. The Lake Natoma water temperatures during the summer are generally much cooler than Folsom Reservoir. Thus the lake is less heavily used as a swimming and wading resources.

5. <u>Folsom Reservoir</u>. - Folsom Reservoir and the Folsom SRA (see Figure H-4) is one of the most heavily used units in the California State Park System. Because of its proximity to a rapidly growing metropolitan area, the hot dry summer climate of the area, the high recreational interest of the surrounding population, and the diminishing open space and recreational resources in the region, Folsom Reservoir is a significant regional and State recreation resource.

With 11,500 surface-acres of lake at gross pool, water-oriented recreation is the major part of Folsom Reservoir usage. These activities include sailing, water skiing, jet skiing, and wind surfing. The upper arms of the lake are designated slow zones for quiet cruising, fishing, and nature appreciation. Folsom Marina in Brown's Ravine provides 670 berthing slips for year-round mooring (if there is sufficient water), along with small craft rental and supplies.

Folsom Reservoir has up to 75 miles of undeveloped shoreline which provides excellent quality sandy swimming beaches, both designated (with lifeguard services) and undesignated. Summer water temperatures average 72 degrees, enhancing both water-oriented and shoreline activities.

Surrounding Folsom Reservoir is a landscape with important scenic, natural, and cultural values. These provide numerous land-based recreational opportunities, such as camping (182

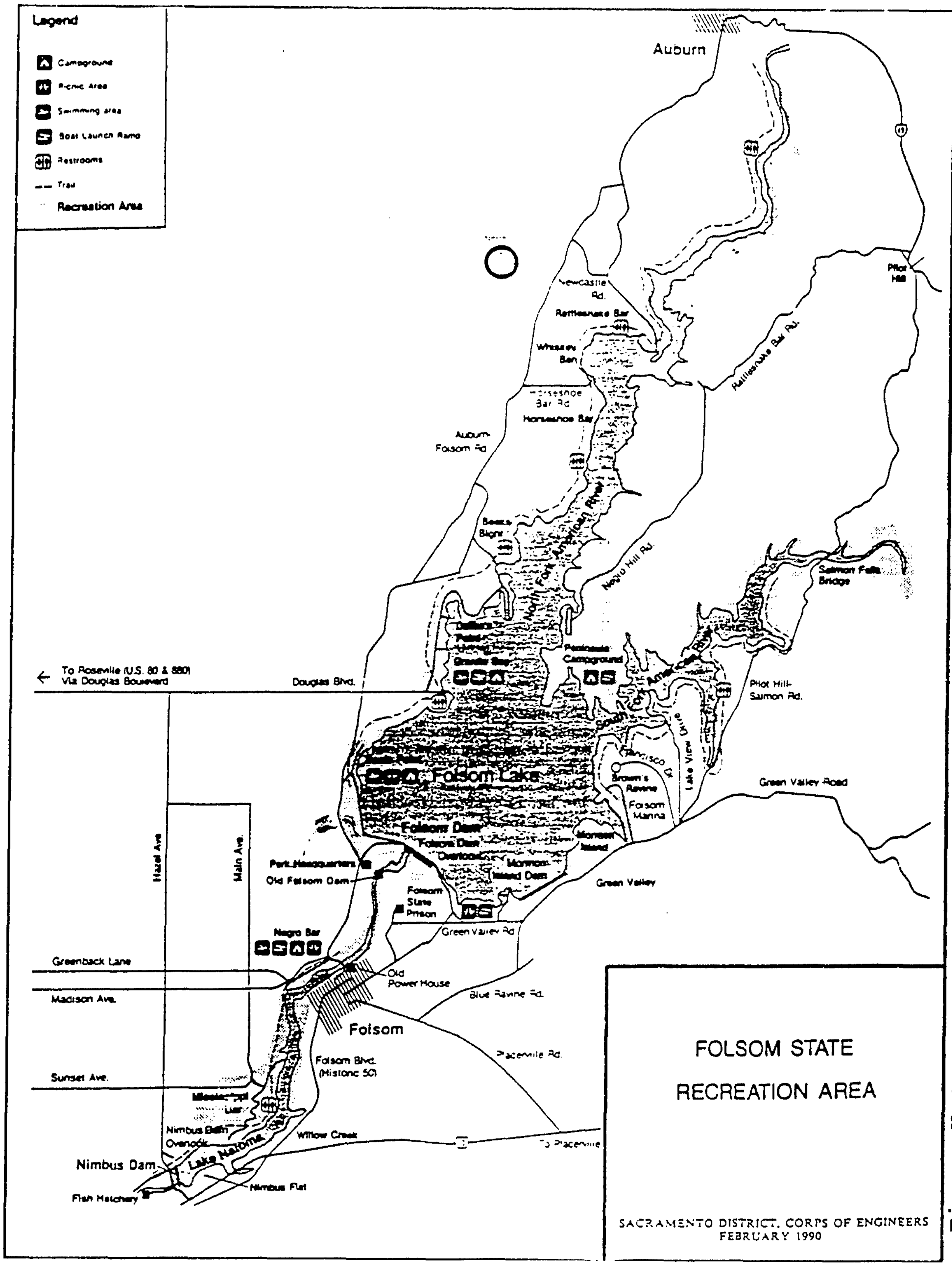

Legend
Campground
Picnic Area
Swimming area
Boat Launch Ramp
Restrooms
Trail
Recreation Area
Auburn
Pilot Hill
Newcastle Rd.
Rattlesnake Bar
Whiskey Bar
Horseshoe Bar Rd.
Horseshoe Bar
Auburn-Folsom Rd.
Rattlesnake Bar Rd.
Beeks Bight
North Fork American River
Negro Hill Rd.
Salmon Falls Bridge
Peninsula Campground
Granite Bay
To Roseville (U.S. 80 & 880) Via Douglas Boulevard
Douglas Blvd.
Pilot Hill-Salmon Rd.
South Fork American River
Lake View Drive
Green Valley Road
Folsom Lake
Brown's Ravine
Folsom Marina
Mormon Island
Folsom Dam
Folsom Dam Overlook
Mormon Island Dam
Hazel Ave.
Main Ave.
Park Headquarters
Old Folsom Dam
Folsom State Prison
Green Valley
Green Valley Rd.
Negro Bar
Greenback Lane
Madison Ave.
Old Power House
Blue Ravine Rd.
Folsom
Folsom Blvd. (Historic 50)
Placerville Rd.
Sunset Ave.
Nimbus Dam Overlook
Willow Creek
To Placerville
Nimbus Dam
Lake Natoma
Fish Hatchery
Nimbus Flat
FOLSOM STATE
RECREATION AREA
SACRAMENTO DISTRICT, CORPS OF ENGINEERS
FEBRUARY 1990

Figure H-4

sites), picnicking (1,419 sites), hiking, and nature study. Approximately 160 miles of unpaved roads and trails are available for hiking and horseback riding, as well as the previously mentioned 8.4 miles of paved bicycle trail which connects with the American River parkway's 26 mile Jedediah Smith trail.

According to the DPR, the optimal lake elevation for recreation use is 436 feet above sea level. At this level, all the facilities are available, and the beaches are large enough to accommodate high use levels. Lake levels higher than elevation 436 reduces the carrying capacity of the lake as boat ramps and parking spaces are eliminated. Most of the boat ramps are unstable around elevation 420, and by elevation 405 only one boat ramp is still usable for boat launching.

Approximately 2.1 million recreation users use Folsom SRA each year. Approximately 95 percent of the day users and one-third of the campers come from the Central Valley, with one-third from the San Francisco Bay area and one-third from other areas. Table H-4 shows the breakdown of visitation by recreation use.

Table H-4

Folsom Reservoir Recreation Use by Type

Activity	Percent of Total	Annual Visitors
Swimming (designated)	14.0	294,000
Camping	3.1	65,100
Windsurfing	1.9	33,900
Picnicking	8.5	178,500
Fishing	19.9	417,900
Boating (launch)	27.9	585,900
Boating (non-launch)	1.8	37,800
Jet Skiing	2.7	56,700
Swimming (non-designated)	13.0	273,000
Berthing	2.6	54,600
Equestrian	1.8	37,800
Boat Camping	0.9	18,900
Hiking	1.7	35,700
Special Events	0.2	4,200
Total	100.0	2,100,000

Visitation data collected from 1976 through 1987 by the DPR showed that the average monthly visitation to Folsom Reservoir is approximately 141,000. This average monthly visitation figure has large variation, depending mainly upon temperature and water elevation in the reservoir. Visitation peaks in the summer and tapers off during the fall and winter (see Table H-5). The lowest use month occurred in December 1982 (7,224 visits), and the highest use month was 502,187 in June 1985.

Table H-5

Folsom State Recreation Area Monthly Use

Month	Percent
January	1.5
February	3.2
March	4.6
April	10.2
May	15.1
June	18.1
July	18.7
August	14.6
September	7.8
October	3.4
November	1.9
December	0.9

Water surface elevations at Folsom Reservoir directly influence the recreational quality of the resource, which in turn affects both attendance and user behavior patterns. The extent to which the resource is affected, and the quantitative impacts, vary from month to month. The main recreational use season, May through August, is most sensitive to water surface elevations. Use patterns during the winter months exhibit a greater degree of flexibility relative to water surface elevations.

Due to physical constraints, aesthetic preferences, facility convenience, and recreational and safety standards, a water surface elevation in the range of 435-450 feet throughout the main recreation season proved to be the most beneficial to all user groups considered. Use through this elevation range is from 94 to 98 percent of the potential maximum attendance. One hundred percent of potential use is never realized, mainly due to use displacement; as conditions become ideal for one activity type, they may deteriorate for another. For example, as water skiing activity increases, windsurfing conditions deteriorate due to wake disturbances, etc. This may result in windsurfers avoiding peak waterskiing periods, or utilizing alternate resources.

The following threshold elevations are based on reservoir physical constraints:

466 feet - full pool; parking areas, day use beaches, and launch ramps submerged.
405 feet - Marina out; no berthing or main launch ramp in service at Brown's Ravine
401 feet - most launch ramps out of service.

6. Upper American River (Auburn) Area. - The upper American River area is comprised of the lands within the boundaries of the USBR Auburn Dam project, on the North and Middle forks of the American River. The USBR has contracted with DPR to provide recreation and public use management services on the lands within the Auburn project boundary. The DPR has designated the area as the Auburn State Recreation Area (SRA). Within the Auburn SRA are approximately 42,000 acres and 48 miles of the North Fork and the Middle Forks of the American River from the Auburn damsite to the Iowa Hill Bridge and the Oxbow Reservoir respectively.

Rushing rapids, punctuated by deep clear pools, within deep canyons, surrounded by wooded ridgelines, characterize the North and the Middle Forks as they cut through Auburn SRA. The juxtaposition of steep terrain and water creates a dynamic setting for a diversity of unique recreational opportunities. Among the recreational activities pursued in the Auburn SRA are:

Whitewater Boating (rafting, kayaking and canoeing)
Power Boating
Flatwater Boating (canoeing and kayaking)
Gorge Scrambling
Nature Study and Appreciation
Horseback Riding
Water Skiing
Camping
Recreational Gold Mining
Hunting
Fishing
Hiking
Swimming
Sunbathing
Historic and Cultural Exploration
Photography
Off-highway Vehicle Use
Mountain Bicycling
Picnicking

The Auburn SRA is especially accessible to the surrounding population due to its location adjacent to major transportation corridors. Interstate (I)-80 lies along the northwest margin of the area and brings it within a two-hour drive from of the San Francisco Bay Area, even less from Reno. State Route (SR) 49 traverses the Auburn SRA from the north and south.

Many qualities of Auburn SRA are sufficiently significant to draw visitors from afar. Participant origin data from competitive equestrian and mountain running events along the Middle Fork indicate regional and National importance. The Tevis Cup (Endurance trail ride) and the Western States Endurance Run (foot race), both one-day, 100-mile events using the Western States Trail, draw entrants from all over the country, as well as considerable international participation. The approximately 72 miles of hiking and equestrian trail, and 15 miles of fire road open to mountain bicycles in the Auburn SRA also provide year-round recreation opportunities.

Whitewater boating on the Middle and North Forks of the American River is of State and National significance. There are no existing river segments within a two-hour time zone of a major metropolitan area comparable to these rivers and canyons. Both forks offer overnight camping opportunities, hiking trails, cultural and natural observation sites, and a diversity of difficulty in whitewater rapids, meeting beginning to advanced boating skill levels.

Also of significance, is the scenic value of the upper canyon; many tributary streams run into the forks of the American at a very steep gradient, creating small cascades and waterfalls. The major rapids on the main stems of the North and Middle Forks provide unique scenic features, in a setting with few visible human intrusions. With the United States losing pristine rivers and their canyon lands at an alarming rate, the North Fork of the American remains one of the last free-flowing rivers in California. Equally significant is the concentration of historic sites and remains in the canyons, especially the Middle Fork.

Because of reasonable proximity, accessibility, high scenic quality, regional uniqueness and excellent whitewater, the Upper North and Middle Forks of the American River and surrounding Auburn SRA are a unique and irreplaceable entity to both the growing Sacramento area and Northern California alike.

The proximity of Auburn SRA to major population centers along with its diverse recreation base, expansive viewsheds and ease of access from major highways, make Auburn SRA one of the most used and significant recreational resources in Northern California. The most popular month for Auburn SRA is July, with 20% of the use occurring in this month. In fact, 46% of the use occurs in the summer months of June, July and August (see Figure H-5).

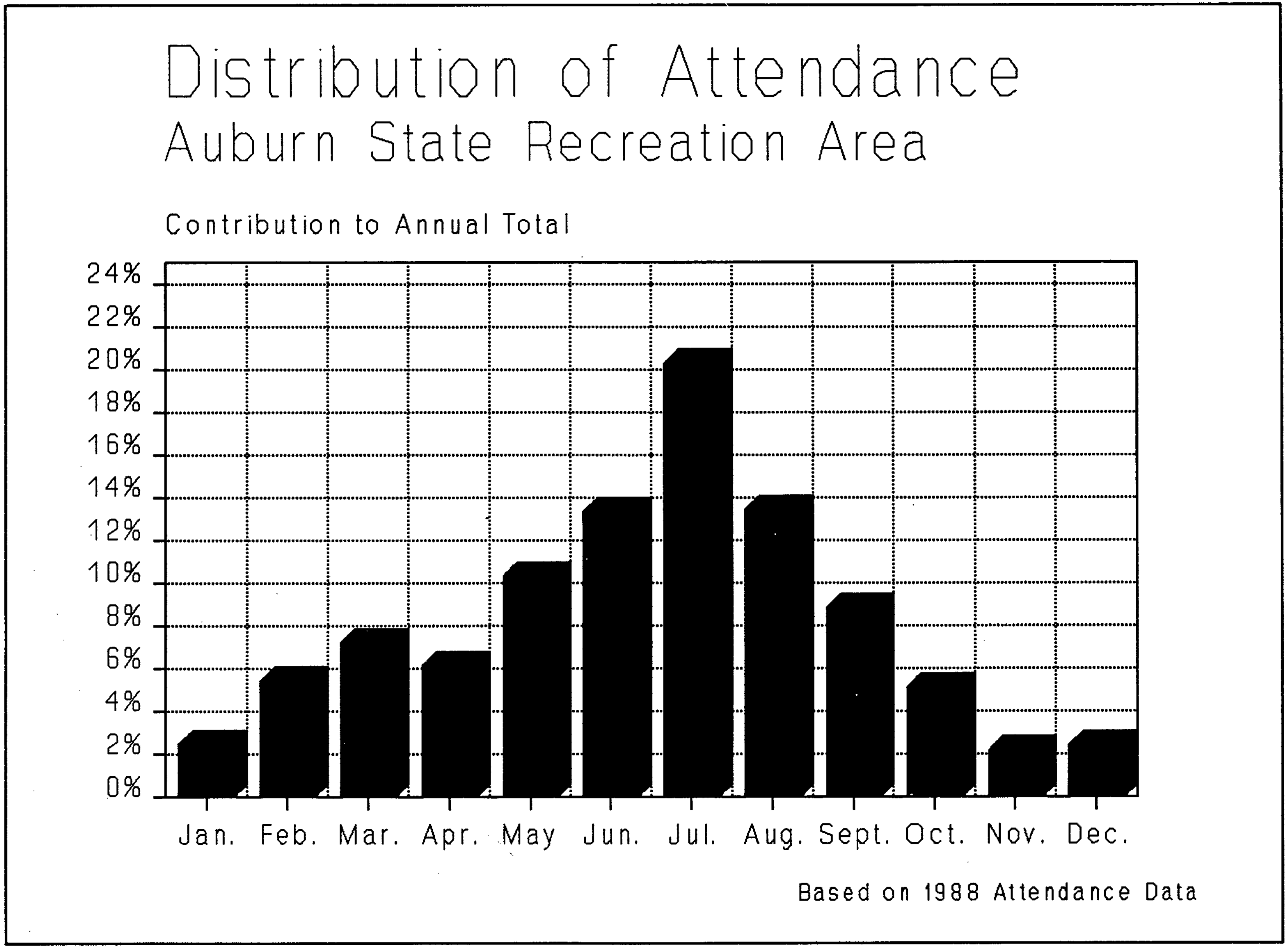

Distribution of Attendance
Auburn State Recreation Area
Contribution to Annual Total
24%
22%
20%
18%
16%
14%
12%
10%
8%
6%
4%
2%
0%
Jan.
Feb.
Mar.
Apr.
May
Jun.
Jul.
Aug.
Sept.
Oct.
Nov.
Dec.
Based on 1988 Attendance Data

Figure H-5

Recreational use of the area tapers off in the fall to a low in winter, increasing once again in spring. All user statistics have been collected by DPR staff.

DPR maintains a staff of State Park rangers and maintenance workers who manage the lands for public enjoyment and recreation. Although DPR is responsible for the recreational aspects of Auburn SRA, USBR pays for all State Park employees, facilities and equipment (such as tools, vehicles, etc.) necessary for the operation of the Auburn SRA. It is USBR's responsibility to make major land use decisions, such as determining where grazing or other commercial land leases can occur. USBR can also close areas of the Auburn SRA to the public. In general, DPR is responsible for the day-to-day visitor-related aspects of Auburn SRA while USBR oversees DPR and makes major land use decisions.

Almost no facility development to support public recreation has occurred within the boundaries of the Auburn SRA because of the assumed inundation which would occur when the USBR Auburn Dam is completed. Thus what recreation does occur is made possible by the natural features of the area, the generally primitive access roads, and the acquisition of approximately 26,000 acres of private land which the USBR acquired prior to the dam construction shutdown in 1975. In the intervening years, public recreation use grown significantly and thus the lack of sanitary and support facilities, and designated sites has resulted in numerous recreation management problems and a degradation of the recreation experience. Citizen volunteer labor is also expended each year to maintain trails and signs, as well as constructing additional trail segments.

DPR has six rangers on staff, patrolling the various locations in the Auburn SRA. The number of rangers patrolling at any one time varies, with all areas being more heavily patrolled during the main use season. The Confluence and Lake Clementine areas are patrolled most frequently, due to heavier use and potential user conflicts. Road maintenance and toilet maintenance is contracted out to private firms, but one maintenance worker and park aids are responsible for general maintenance and litter pick-up.

The USBR contracts with the California Department of Forestry (CDF) for fire protection; the county sheriffs, together with DPR, are responsible for search and rescue efforts in the Auburn SRA. On the Middle and North Fork whitewater runs, generally well equipped and experienced boaters are capable of self or group supported rescue. However, there have been several instances where the help of local emergency response organizations was required.

The California Department of Fish and Game (DFG) administers dredging permits for gold miners and administers hunting. DFG wardens patrol Auburn SRA to make sure that hunters comply with regulations and have valid hunting permits.

On the upper reaches of the Middle Fork, the Auburn SRA overlaps with the lands of the El Dorado and Tahoe National Forests. These lands are managed by the United States Department of Agriculture, Forest Service (USFS) and comprise approximately 2,400 acres within the Auburn SRA boundary. The USBR has not withdrawn the USFS lands for the Auburn Dam project, therefore the USFS continues to manage these lands. The primary put-in for the Middle Fork of the American River whitewater run (Oxbow) falls on the National Forest lands. However, since most of the run is within the jurisdiction of DPR, DPR manages whitewater outfitter-guide activity on USFS land through a USFS and USBR agreement.

The CDF, under contract with the USBR and through an agreement with U.S. Fish and Wildlife Service (USFWS), oversees fire prevention and fire suppression programs in the Auburn SRA. As a result of the Federal Fish and Wildlife Coordination Act, Federal agencies who alter water resources are required to coordinate with the USFWS. To mitigate interim impacts to wildlife habitat in Auburn SRA which have occurred as a result of initial construction on the multi-purpose Auburn Dam project, USFWS has advised USBR to implement habitat modifications and improvements as wildlife habitat mitigation. USBR contracts with the CDF to use prescribed burning and crushing techniques to initiate regrowth of palatable forbs and shrubs and to open up the dense chaparral for greater wildlife utilization.

Although the Bureau of Land Management (BLM) holds numerous scattered parcels of land within the Auburn SRA, the USBR has either withdrawn the lands from the public domain or has applied for withdrawal of the lands. USBR has assumed full management responsibilities for the 7,200 acres of currently withdrawn land. BLM manages the additional 6,500 acres within the Auburn SRA for which withdrawal is pending.

The Auburn SRA/upper American River area can be divided into six major recreational use areas, 1) The State Route (SR) 49 Corridor, 2) Lake Clementine, 3) Upper North Fork of the American River, 4) Upper Middle Fork of the American River, 5) Knickerbocker Flat, and 6) Forest Hill Divide. A description of each area follows. Figure H-6 provides a breakdown of usage at specific recreation sites within the six major recreational use areas. Table H-6 provides a listing of existing facilities.

a. <u>The Highway/State Route (SR) 49 Corridor</u>. - The SR 49 Corridor area covers approximately 400 acres along roughly 3 miles of river, where SR 49 and the Old Foresthill Road descend

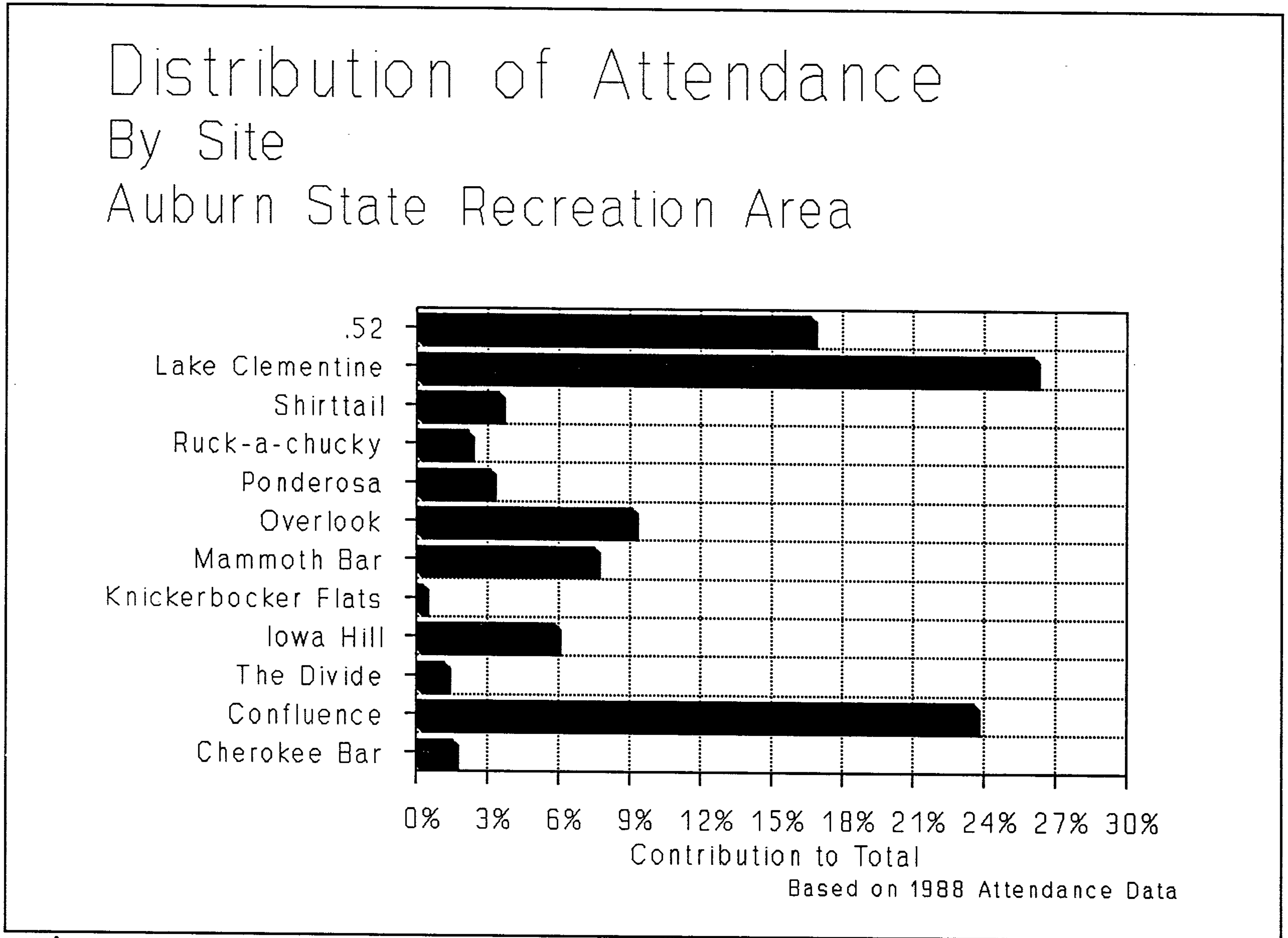

Distribution of Attendance
By Site
Auburn State Recreation Area
.52
Lake Clementine
Shirttail
Ruck-a-chucky
Ponderosa
Overlook
Mammoth Bar
Knickerbocker Flats
Iowa Hill
The Divide
Confluence
Cherokee Bar
0% 3% 6% 9% 12% 15% 18% 21% 24% 27% 30%
Contribution to Total
Based on 1988 Attendance Data

Figure H-6

TABLE H-6

EXISTING IMPROVEMENTS

	Parking	Picnic	Restrooms	Campsites	Access Facilities (see text)	Special Facilities (see text)
Confluence	150	0	Primitive	0	None	None
.52	N/A	0	None	0	None	None
Mammoth Bar	N/A	0	None	0	None	None
Lake Clementine	25 Car 25 Trls	0	Primitive	21	Yes	Yes
Upper Lake Clementine	30	0	Primitive	Open	None	None
Cherokee Bar	30	0	Primitive	15	None	None
Ruck-a-Chucky	20	0	Primitive	10	Yes	None
Ponderosa	N/A	0	None	0	None	None
Shirtail Canyon	N/A	0	Primitive	0	None	None
Iowa Hill Bridge	30	0	Yes	18	Yes	None
Oxbow	N/A	0	Primitive	Open	None	None
Knickerbocker Flats	100	0	None	0	None	None
Foresthill Divide	40	0	None	0	None	None

into and cross the North and Middle Fork Canyons. Parking and access is available along either of these roads at various informal pull-outs, and at a separate trailhead parking area. Throughout this general area dispersed recreational activities take place, though most are river oriented. Anglers can be found on almost any stretch of the river, as well as picnickers, sunbathers, hikers, equestrians, mountain bikers and others seeking to enjoy the river and canyon setting.

The Highway 49 corridor can be divided into three sub areas, the Confluence, .52, and Mammoth Bar.

1) The Confluence. - The Confluence consists of a large gravel/sand beach area where the North and Middle Forks of the American River join. This area receives the second greatest amount of visitation in the Auburn SRA. This open area is accessed by SR 49 on the south and Foresthill Road on the northeast. Because of the ease of accessibility and visibility off of SR 49, this area is the best known among the general public. There is year-round river flow due to releases from the dams upstream on the Middle Fork of the American River. The stream channel morphology ranges from a low gradient gravel bar rapid to a relatively deep runout with strong hydraulics evidenced both on, and below the water surface, ending in a slow moving deep channel.

The ease of access, large beach areas, and dynamic water features are the main attractions in this area. Swimming, hiking, mountain bicycling, fishing and sunbathing are the main activities at the Confluence. The proximity of steep shady hillsides to sparkling cool waters make visiting this area a popular summertime activity. The Old Mountain Quarries Road/Railroad Trail begins at the Confluence and extends east along the Middle Fork of the American River beyond Murderers' Bar. The 10 to 15-foot width and gentle gradient of the trail make it very popular with hikers, mountain bicyclists and equestrians. A portion of the Western States Trail, a federally designated National Recreation Trail, passes just below the actual confluence of the two forks, crossing the river at "No Hands Bridge", and continues upgrade into the city of Auburn. This historic trail, which originally stretched from Sacramento to Utah, is heavily used by hikers, runners and equestrians. The Sierra Crest portion of the trail, blazed by Paiute and Washoe Indians and later used by miners, is now the route of two world-famous, 100-mile endurance races; one race for runners called the Western States Endurance Run and one for equestrians called the Tevis Cup. In addition, there are various trails in the area which connect Auburn, Folsom Lake, Lake Clementine, and the Cool area.

The Confluence receives most of its use (47%) in the summer months (June through August), with the most popular month being July, although it receives at least some use year round (see Figure H-7).

The Confluence has no developed facilities aside from a small trailhead parking area for the Mountain Quarries Trail and various pull-outs which can accommodate approximately 150 automobiles. Recreation management problems at the Confluence are mainly due to the lack of designated and sufficient parking facilities, and the ease of motor vehicle access. In addition, due to the variety of activities occurring at the confluence, and the lack of designated facilities to separate differing user groups, conflicts are inherent.

2) .52. - Half a mile downstream of the Confluence on the North Fork is an area referred to as .52, which serves as a de facto nude beach. The .52 area accounts for the third largest use in the Auburn SRA. This area is normally accessed via a steep trail down the north side of the canyon from SR 49. A smaller portion of users hike in from the Confluence area on the Old Mountain Quarries Railroad/ Western States Trail. This use area is situated in a deep canyon environment with the river features dominated by deep slow moving pools, ideal for swimming. The steep canyon walls provide a measure of privacy for nude sunbathing and swimming. Parking for .52 is limited to pullouts along Highway 49. The limited parking and nude sunbathing at .52 are factors which limit use of this area.

.52 receives the heaviest use (44%) in the summer months (June through August), with the most popular month being July, although it receives at least some use year round (see Figure H-8).

Management problems at .52 include lack of toilet facilities, steep eroding hillsides cut with de facto trails, and inadequate parking. Most of the parking for the area is located on the north side of a steep, winding section of SR 49, creating an unsafe situation when people cross the highway to get to the trail leading to the .52 area. As at the Confluence area, user conflicts sometimes occur.

3) Mammoth Bar. - Approximately one and a half miles upstream of the Confluence on the north bank of the Middle Fork of the American River is a 20-acre area referred to as Mammoth Bar. This area, accessed via a steep dirt road off the Old Foresthill Road, consists of a large sand and gravel bar adjacent to the river. The primary recreational use of this area is an off-highway vehicle (OHV) use area (motorcycles, three- and four-wheel all terrain vehicles, etc.). OHV activity generally would not be permitted directly adjacent to a river elsewhere in the State parks system, however, this OHV area was originally

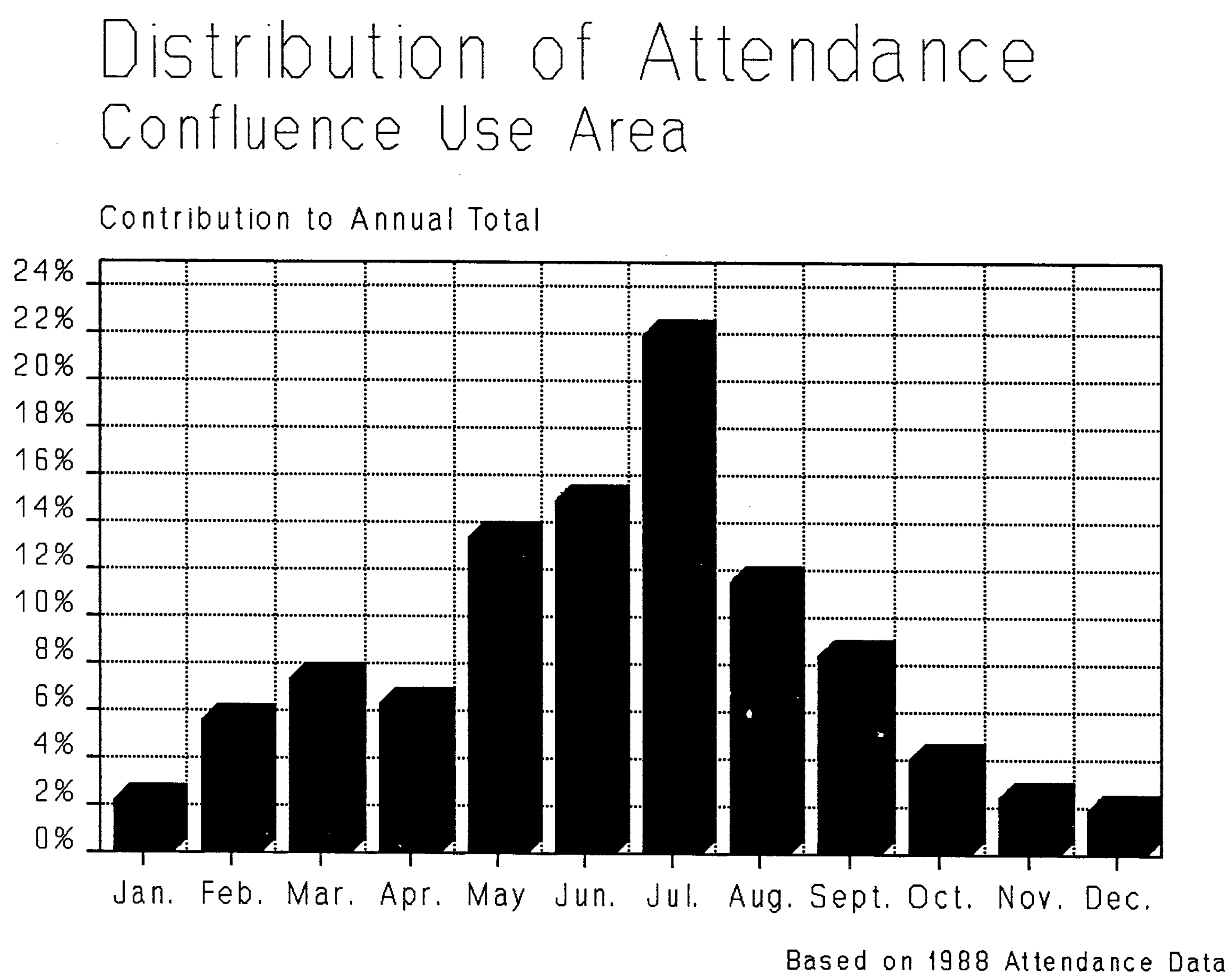

Distribution of Attendance
Confluence Use Area
Contribution to Annual Total
24%
22%
20%
18%
16%
14%
12%
10%
8%
6%
4%
2%
0%
Jan.
Feb.
Mar.
Apr.
May
Jun.
Jul.
Aug.
Sept.
Oct.
Nov.
Dec.
Based on 1988 Attendance Data

Figure H-7

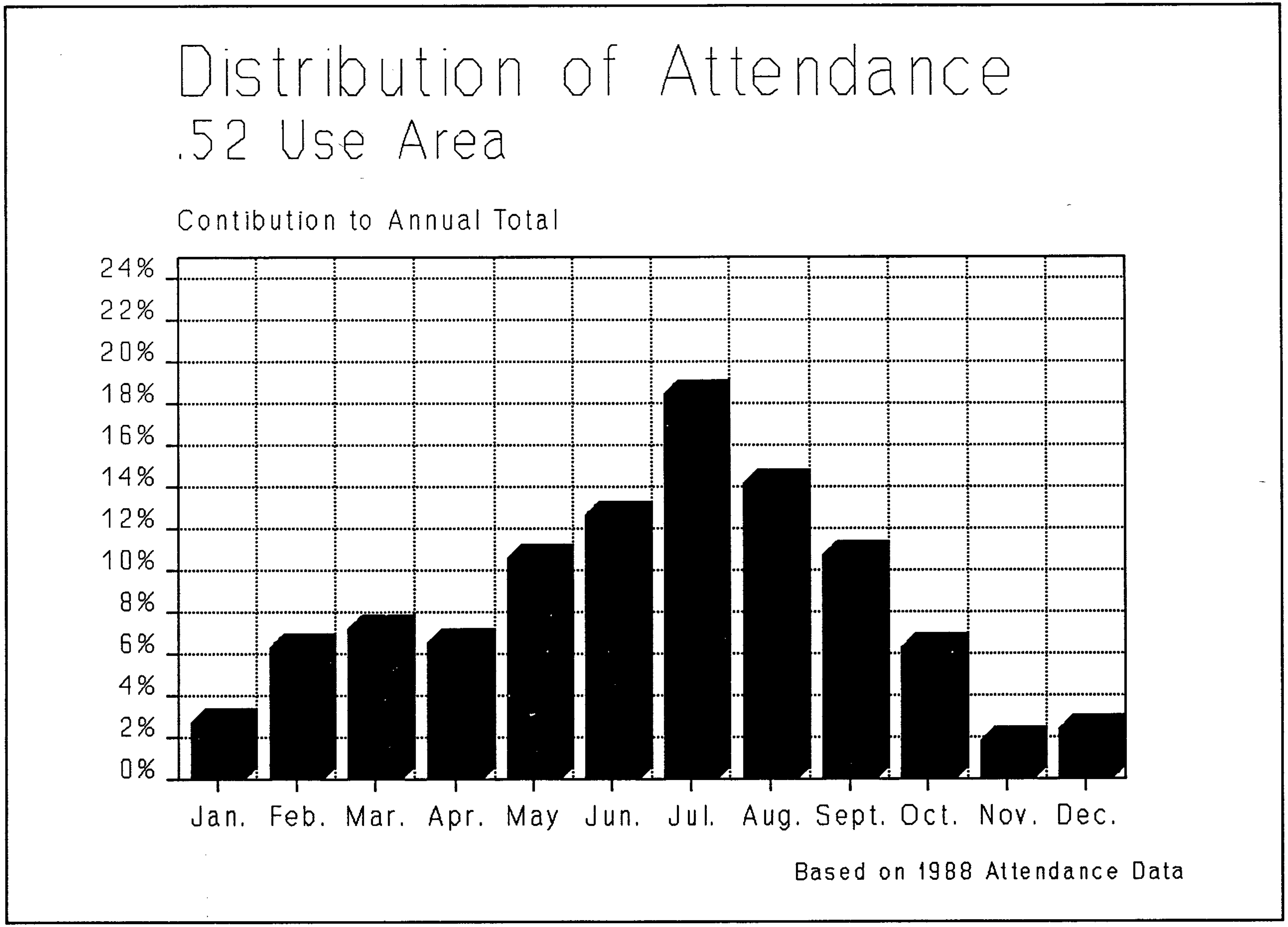

Distribution of Attendance
.52 Use Area
Contibution to Annual Total
24%
22%
20%
18%
16%
14%
12%
10%
8%
6%
4%
2%
0%
Jan.
Feb.
Mar.
Apr.
May
Jun.
Jul.
Aug.
Sept.
Oct.
Nov.
Dec.
Based on 1988 Attendance Data

Figure H-8

condoned due to the "interim" nature of the resource base, as the area was to inundated by the USBR multi-purpose Auburn Dam reservoir. Numerous trails and informal race courses have been created which take advantage of the washes and changes in topography. Users have also established trails outside the boundaries of this OHV area which lead up the adjacent canyon slopes.

Compared to other OHV areas in the State Park System, the area at Mammoth Bar is relatively small. The high potential for resource damage (vegetation destruction, soil erosion, and sedimentation) and conflicts with other users of the Auburn SRA has prevented the USBR and DPR from allowing expansion of the Mammoth Bar OHV area.

Other types of recreation use do take place at Mammoth Bar. Located on a level gravel/sand bar with easy access to the river shore, this area is used by swimmers, sunbathers, picnickers and bank fisherman. Easy vehicular access to the waters edge makes Mammoth Bar an occasional take-out site for the Murderer's Bar run on the Middle Fork of the American River.

Mammoth Bar shows no pattern of seasonal use. The month experiencing the most use is September (14% of the use in the area). The remaining months all experience between 4% and 10% of the total use for the Mammoth Bar area (see Figure H-9).

The area suffers from the problems associated with lack of toilet facilities, out of bounds OHV use causing erosion and scaring of the hillsides, and conflicts between the diverse user groups using the area.

4) <u>Lake Clementine</u>. - Lake Clementine, covers approximately 400 acres and is located approximately two miles upstream of the Confluence area on the North Fork of the American River. The primary access is via a narrow paved road; secondary access is via an unpaved road connecting the east end of the lake with the Foresthill Divide.

Formed by the North Fork Dam, Lake Clementine, a five-mile long reservoir, is the focal point of this area. Built in the 1939 by the Army Corps of Engineers, the sole purpose of the dam is to retain mining debris and sediment; it serves no hydroelectric power, flood control, or water storage/release function. As a result, the lake maintains a stable water level elevation of 715-feet year-round, enabling lush riparian vegetation to grow to the lakes edge. This creates a thriving habitat for fish and other wildlife, and has resulted in a man-made lake which is visually more attractive than most man-made impoundments. Nestled in a steep canyon, a prominent limestone outcropping, known as Robbers' Roost or Lime Rock, is the dominant landscape feature of this highly scenic area.

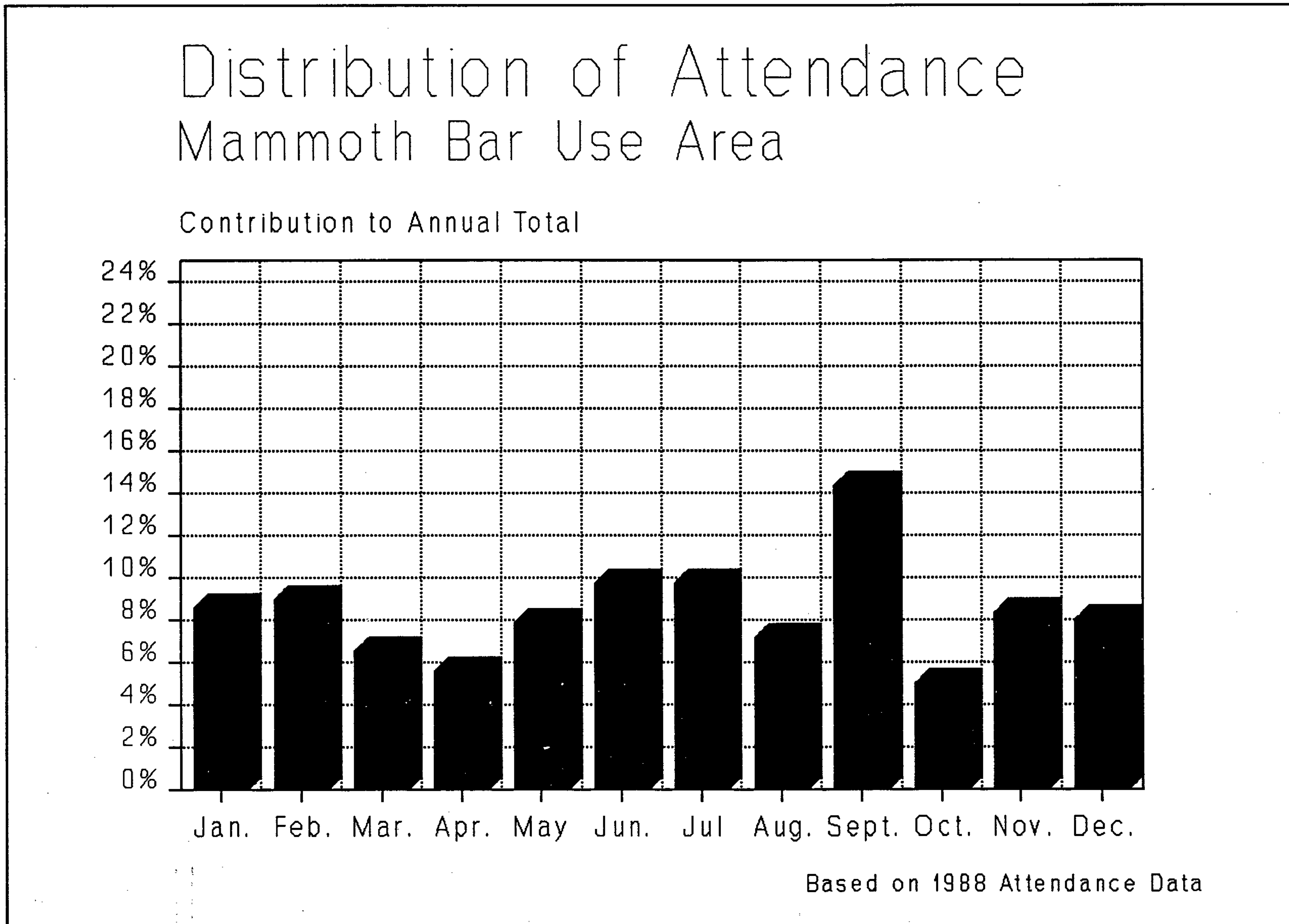

Distribution of Attendance
Mammoth Bar Use Area
Contribution to Annual Total
24%
22%
20%
18%
16%
14%
12%
10%
8%
6%
4%
2%
0%
Jan.
Feb.
Mar.
Apr.
May
Jun.
Jul
Aug.
Sept.
Oct.
Nov.
Dec.
Based on 1988 Attendance Data

Figure H-9

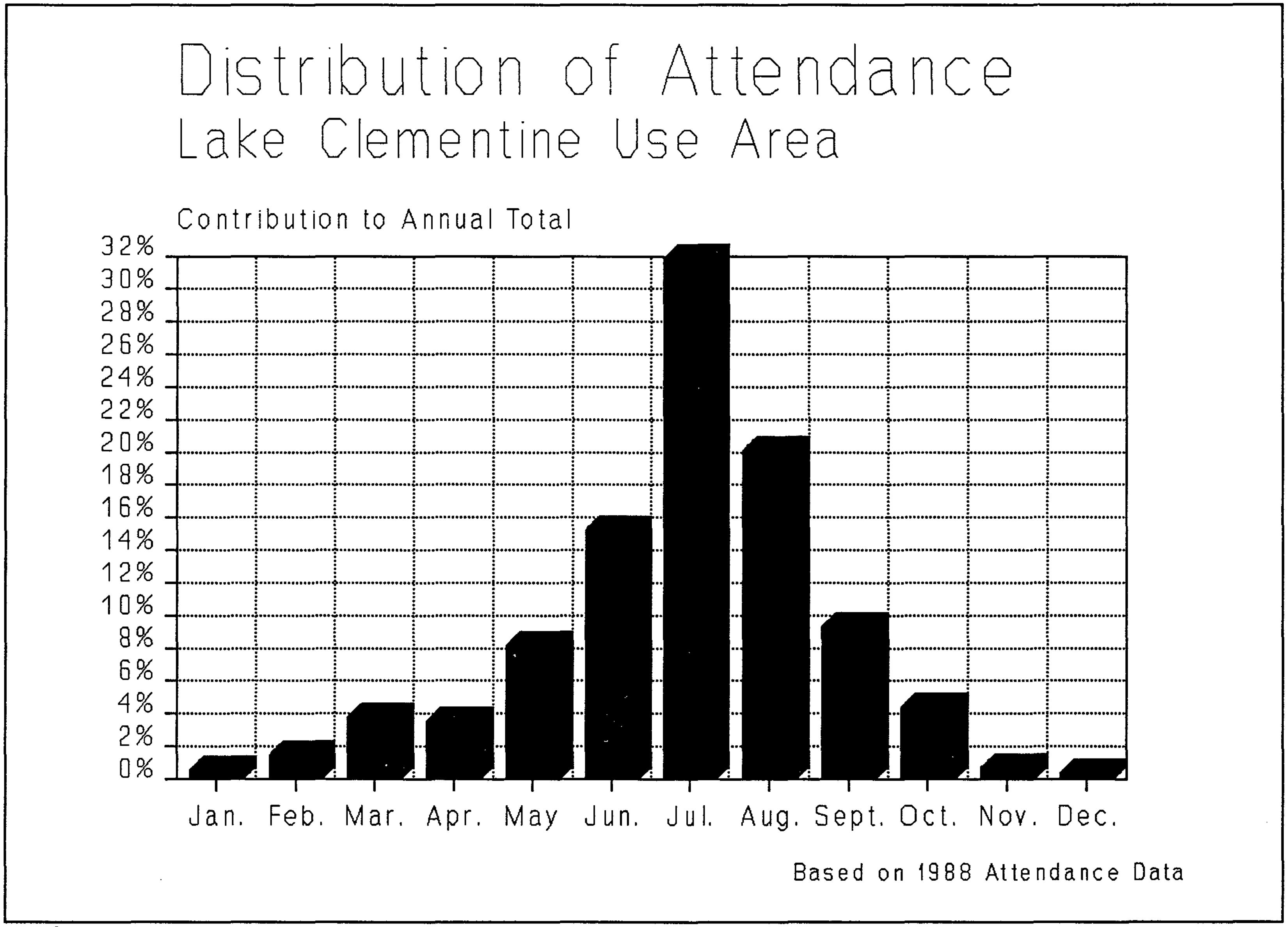
The combination of a relatively large flatwater area with a very scenic backdrop sets the stage for some popular recreational activities, including fishing, water-skiing, canoeing and boat-in and drive-in camping.

The Lake Clementine area is the most popular use area in the Auburn SRA. It receives the heaviest use in the summer month, with 65% of the use occurring between the months of June through August and less than 5% of the use occurring between the months of November through February (see Figure H-10).

The Lake Clementine Area can be divided into two sub areas; the lower end of Lake Clementine and the upper end of Lake Clementine. The lower portion of Lake Clementine can be accessed via the paved North Fork Dam Road, which is open year round. This lower portion offers opportunities for water skiing and warm-water sport fishing. On the lake is a single lane boat launch ramp, courtesy dock, and the Auburn Boat Club, a private organization operating a 50-slip marina and public fuel sales as a DPR/USBR permitted concession. Because, for reasons mentioned above, Lake Clementine is more visually attractive than most other man-made water impoundments, it is a very popular place to enjoy water-skiing. The relatively small size of the lake (342 acres, permitting water-skiing in one direction only) in conjunction with limited parking facilities (spaces for 25 cars and trailers) which fill quickly in summer, limit recreational use at Lake Clementine.

The upper end of Lake Clementine can be reached via a dirt road, open from April or May to late fall and closed during the rainy season. The road terminates at a gravel bar with a parking area, picnic area, 15 primitive drive-in campsites and access to the water. Due to the shallow nature of the lake at its' upper end, it is closed to motorized boats. Visitors are attracted to this end of the lake to enjoy more passive lake activities such as flatwater kayaking, canoeing, swimming and water play. In addition to the drive-in campsites, there are primitive boat-in campsites located on three separate sandbars at the upstream end of the lake. The primitive nature of the area is considered by users to be a positive attribute, and there is a tradition of use; people camping there now camped there as children.

The most acute management problem at Lake Clementine is the lack of adequate toilet facilities. A floating vault-type restroom, which can be pumped out periodically into a pumper truck is to be placed on the lake in 1990. In addition there is a lack potable water, congestion caused by the narrow roads, and small amount of parking available.



Distribution of Attendance
Lake Clementine Use Area
Contribution to Annual Total
32%
30%
28%
26%
24%
22%
20%
18%
16%
14%
12%
10%
8%
6%
4%
2%
0%
Jan. Feb. Mar. Apr. May Jun. Jul. Aug. Sept. Oct. Nov. Dec.
Based on 1988 Attendance Data

Figure H-10

b. Upper North Fork of the American River. - Whitewater boating, hiking, gorge scrambling, fishing, camping, gold mining, equestrian use, mountain bike use, picnicking, and a variety of other dispersed recreational activities occur throughout the Upper North Fork of the American River Area.

The aesthetic quality of both the canyon and the river are exceptional. With no upstream dams, the North Fork of the American River is one of the last free flowing rivers in California. Upstream of the USBR/Auburn SRA boundary, the North Fork has been designated a Federal wild and scenic river. The designation ends at the Auburn SRA boundary due to the assumed completion of the USBR Auburn Dam and resultant inundation of this section of river. However, the physical nature of the river within the Auburn SRA above Lake Clementine is no different from the previously designated upper reaches. The streambed morphology is referred as "pool and drop." Most of the rapids are short and steep, surging into pools before and after. The river channel is relatively narrow with many mid-stream obstacles. As an uncontrolled river, the "use season" for boating activity varies, depending on the water content of the snowpack in the drainage and the seasonal temperatures dictating the beginning of "spring runoff." Typically, the boating season runs from May to mid-June. Some winter boating takes place but is limited in numbers. Because of the unpredictable nature of the North Fork's flows and usable season, there is limited commercial interest in running it. Also there are a limited number of commercial whitewater boating permits available for the North Fork. Because commercial boating is more limited on this Fork than either the South or Middle Forks, the North Fork provides a more peaceful recreation experience for noncommercial boaters.

There are two whitewater runs along this section of river. Beginning at Iowa Hill Road and extending to Shirttail Canyon, a 4.5 mile run with a gradient of 50 feet per mile provides a challenging class IV run. From Shirttail Canyon to Ponderosa Way, a five mile run, the gradient lessens to 20 feet per mile and is considered class II - III. The remaining 9 miles to Lake Clementine are rarely utilized by boaters, but do provide additional fishing and hiking areas.

As the stream flows subside in June and the water temperature increase, there is a marked increase in swimming and waterplay activities. Also during the mid-summer low water season, hikers scramble, swim and float sections of the upper North Fork. This technique is the only way for non-boating visitors to access these remote sections of the river.

Within the upper North Fork of the American River are three sub-areas; Iowa Hill, Shirttail Canyon, and Ponderosa.

1) <u>Iowa Hill Bridge</u>.- Iowa Hill Bridge, marks the northern/ upstream end of the Auburn SRA, is located just downstream (less than 1,000 feet) of the wild and scenic designated reach of the North Fork of the American River. The Iowa Hill Bridge area can be reached via Iowa Hill Road off I-80 from Colfax, or from the Foresthill Divide Road. This area serves as the put-in for the Chamberlain Falls run. Aside from boating, this area provides sunny and shady river-side areas which allow for a variety of uses, including recreational gold mining, fishing, hiking, camping, swimming and picnicking. A shady campground located on the south bank of the river is primarily used by non-boaters. Camping is limited by the number of campsites, which reach capacity in the summer. Pit toilets and portable chemical toilets are located on the south bank near the campground. Commercial whitewater rafting outfitters put-in on the north bank. The heaviest use of this area occurs in summer, June - August (see Figure H-11). Although there is some year round use.

The problems at the Iowa Hill Bridge campground result mainly from user conflicts between whitewater boaters and campers. The noncommercial put-ins located in the campground and the level of whitewater activity during peak season weekends tends to create a sense of crowding for the campground users.

Management problems at the commercial put-in area occur mainly because of the high use levels associated with peak season commercial activity. There are no restroom facilities on this bank and the parking/staging area is very limited in size. A relatively steep gravel trail from the staging area to the river bank creates a hazard for commercial guides and passengers and the trail is resulting in erosion of the hillside.

2) <u>Shirttail Canyon</u>. - The Shirttail Canyon area can be reached by taking Yankee Jim Road East from Weimar (on I-80). Here, under the shade of trees, Shirttail Canyon drains into the North Fork. There is no designated camping area. Shirttail Canyon is often used by noncommercial whitewater boaters as a take out for the Chamberlain Falls run; commercial boaters are not permitted to utilize this take-out. Because there is no commercial boating activity at Shirttail Canyon, it tends to be more peaceful and family oriented area than Ponderosa. There are several popular hiking trails in the area, one of which wanders up Shirttail Canyon. Dredging and other recreational gold mining also occurs in Shirttail Canyon.

The take-out trail from the North Fork to the road at Shirttail Canyon is difficult, steep and strenuous for rafters. While kayakers can negotiate the trail without much difficulty, the inconvenience of the take-out trail deters rafter parties from using the area as a take-out and they generally use the Ponderosa take-out. Parking and turn-around areas are limited at

Distribution of Attendance
Iowa Hill

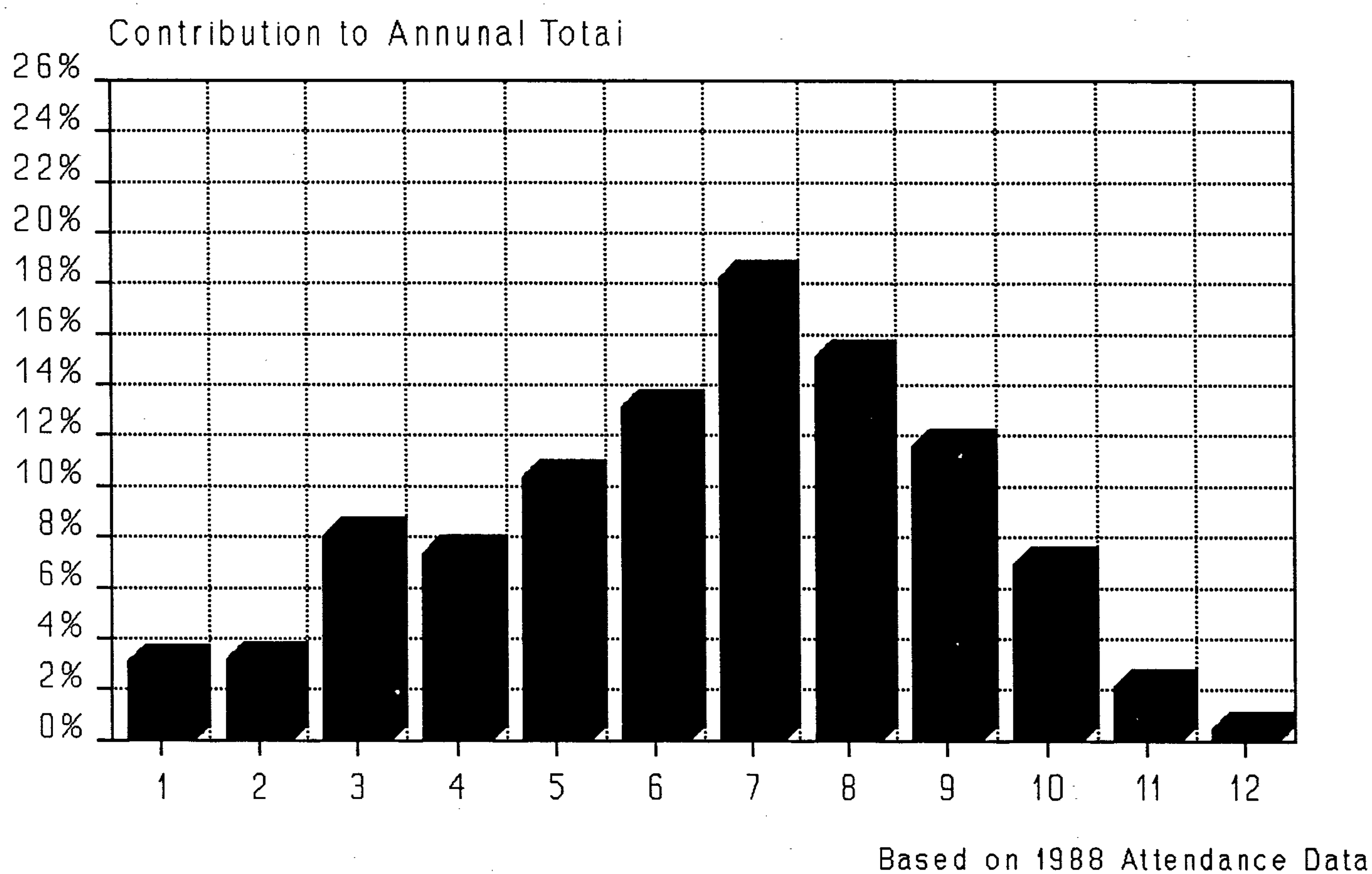


Figure H-11

Shirttail Canyon.

3) Ponderosa. - The Ponderosa area can be reached by the unpaved Ponderosa Way from either Weimar (off I-80), or off of the Foresthill Divide Road. The north bank road from Wiemar is in better condition and receives the majority of use. Similar to the other areas on the Upper North Fork, Ponderosa's main attractions include the river and river oriented activities. This area is the primary take-out for the Chamberlain Falls run. There are no developed facilities at the site and parking is limited to the shoulders of the narrow road, which reaches capacity in the spring and summer. Aside from whitewater use, dispersed day use activities such as picnicking, swimming, sunbathing, fishing and hiking occur. Several large deep pools make swimming a popular summertime activity here. Figure H-12 shows the seasonal usage at this site.

Management problems are associated with lack of facilities and parking to support both the boating and other non-boating users. The narrowness of the dirt access road in conjunction with the very limited parking creates serious congestion during peak use periods. School busses used by commercial whitewater outfitters, and the crowds of people associated with trip take-outs; tend to displace non-boating day-use during the afternoon and evening. User conflicts associated with this displacement are common. Lack of toilet facilities in the area may also create a health hazard.

c. Upper Middle Fork American River. - The Upper Middle Fork area extends from the upstream end of Mammoth Bar to Oxbow Powerhouse. Recreational use activities in this area are similar to those of the North Fork; however there is much heavier gold mining activity in the area.

The nature of the Middle Fork differs markedly from the North Fork relative to channel size, streambed morphology, and use season. The channel is wider and instead of "pool-and-drop", the rapids are longer and flatter. The watershed of the Middle Fork is almost twice the size of the North Fork (614 square miles vs. 342 square miles), which results in larger flows. Stream flow in the Middle Fork is regulated by releases from Oxbow Powerhouse and other dams upstream, thus the boating season usually begins in late May and extends into September (97% of the annual use occurs in this period). Summer river releases during an average precipitation year are approximately 1,200 cfs. Because of the dependable stream flow associated with the Middle Fork, this section of river sees the greatest amount of whitewater boating in the Auburn SRA. The dependability of flows also serves to concentrate the commercial rafting activity operations on the Middle Fork.

There are two distinct runs on this river; Oxbow Powerhouse

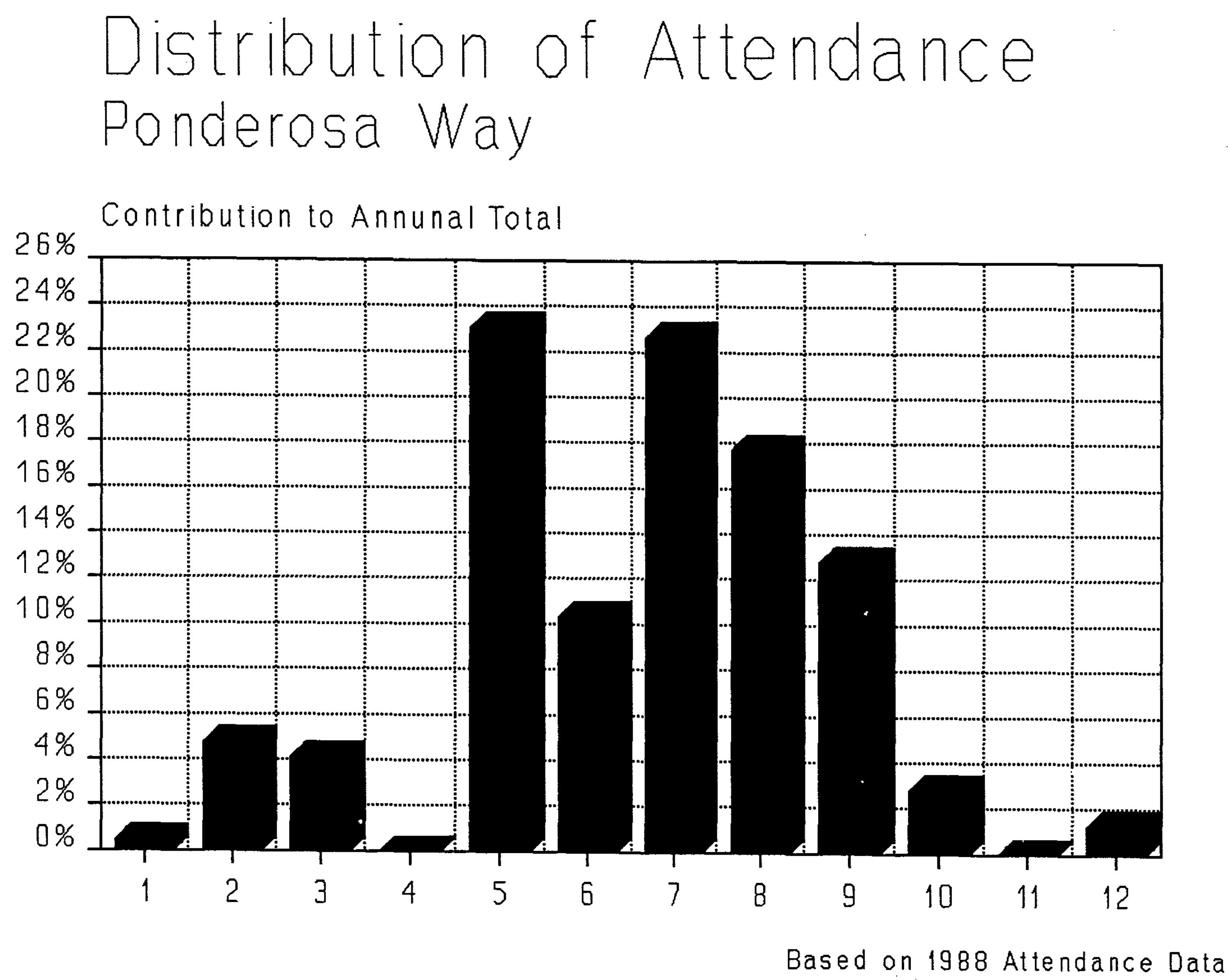

Distribution of Attendance
Ponderosa Way
Contribution to Annunal Total
26%
24%
22%
20%
18%
16%
14%
12%
10%
8%
6%
4%
2%
0%
1
2
3
4
5
6
7
8
9
10
11
12
Based on 1988 Attendance Data

Figure H-12

to the old Greenwood Bridge (Ruck-a-Chucky), and the old Greenwood Bridge to SR 49 or Mammoth Bar. Oxbow to Greenwood Bridge has a gradient of 29 feet per mile, and excluding a rapid called "Tunnel Chute", is a class III - IV run. From Greenwood Bridge to SR 49, the gradient lessens to 19 feet per mile, and with one portage at Ruck-a-chucky, is class II - III.

Angling on the Middle Fork is generally excellent. There is also abundant evidence of historical mining along this river. There are three major use areas located along the Upper Middle Fork; Oxbow Powerhouse, Cherokee Bar and Ruck-a-Chucky.

1) Oxbow Powerhouse Put-in Site. - The Oxbow site, is located on National Forest lands upstream of the Auburn SRA boundary. However, because it is the put-in for the whitewater run of the Middle Fork within the Auburn SRA, the DPR manages the whitewater boating activity at this site.

The primary use at Oxbow is associated with commercial whitewater rafters (98%). A difficult vehicle shuttle and the heavy commercial activity tends to discourage noncommercial boating activity. The lack of shading vegetation, limited water access and lack of beach area make the Oxbow put-in area unattractive to most non-boating recreational users. Minor recreational mining and fishing activity occurs downstream of the put-in area.

Facilities at Oxbow include a seasonal portable chemical toilet, operated cooperatively by commercial whitewater rafting companies, garbage cans and a primitive U.S. Forest Service campground.

Management problems at Oxbow include, the lack of permanent toilet facilities, a steep and narrow trail from the staging area to the water, and severe raft congestion at the put-in pool due to the limited useable bank area and irregular water release times from the Oxbow powerhouse. The barren, unshaded nature of the site also discourages non-boating recreation use.

2) Ruck-a-Chucky. - Ruck-a-Chucky is accessed on a steep unpaved road which descends into the canyon from the Driver's Flat and Foresthill Divide Road. Prior to 1964 the road crossed the Middle fork on the Greenwood Bridge and continued up to the Georgetown area. However, the Greenwood bridge washed out in the 1964 Hell Hole Dam failure flood and has not been replaced. Nestled along the river in the deep canyon, this area is the major take-out for the Tunnel Chute Run and put-in for the Murderers' Bar run. Relatively easy automobile access, drive-in camping and the lazy pace of the river below the rapids also make this area popular for recreational gold miners. The lower end of the road, from Greenwood Bridge to Ruck-a-Chucky Falls, which was closed by washouts in 1986, is popular with hikers, mountain

bicyclists and equestrians. Facilities at Ruck-a-Chucky include pit toilets, parking pullouts, and 10 designated campsites. A volunteer campground host collects camping fees during the spring, fall, and summer. With the limited camping and parking, visitors during the summer often exceed available facilities.

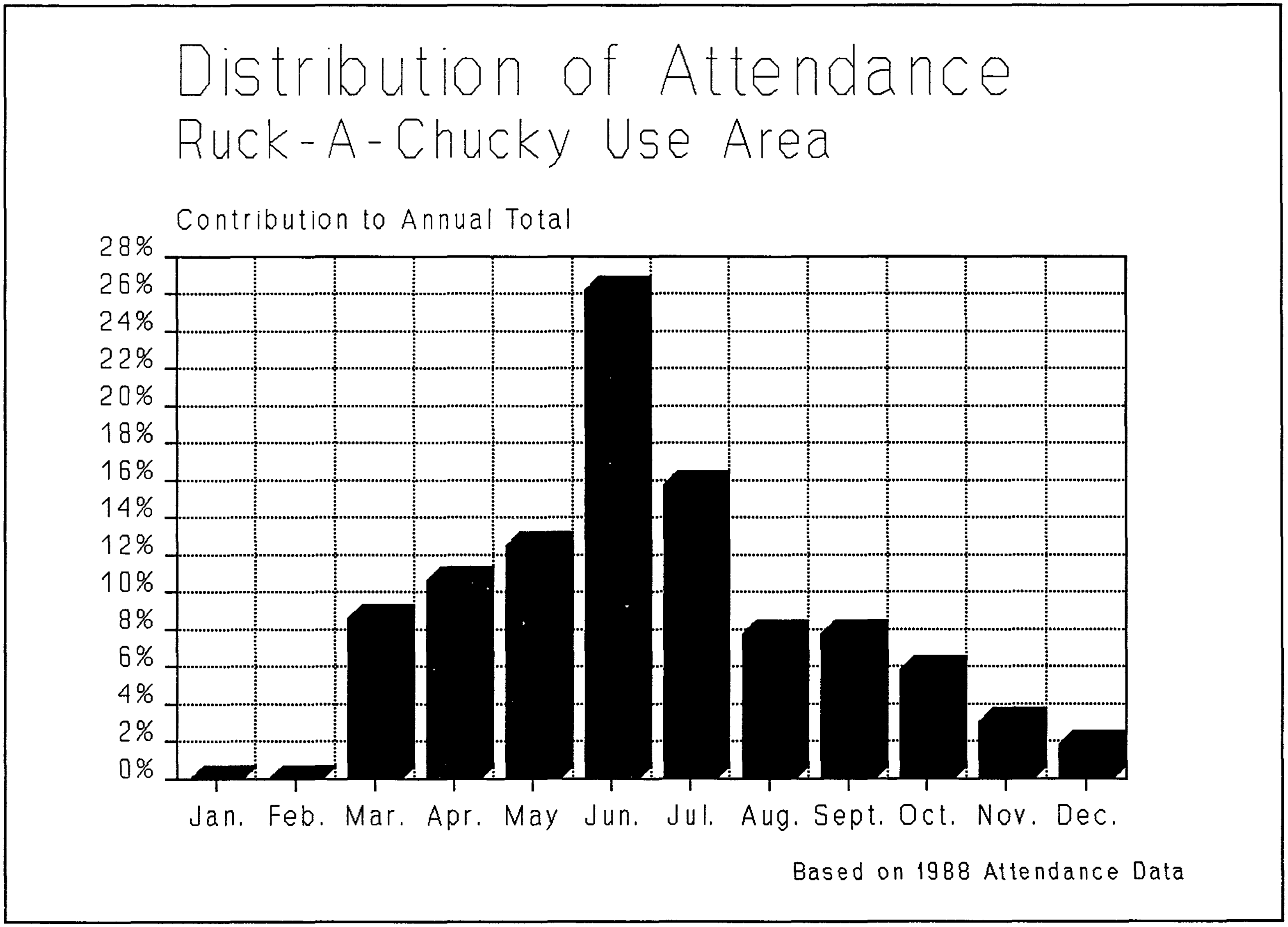
Ruck-a-Chucky receives most of its use in June (26%), with 48% occurring the summer months, 30% occurring in the spring months, and negligible use occurring in the winter months, possibly due to the slick nature of Driver's Flat Road during the rainy months and the seasonal nature of whitewater rafting (see Figure H-13).

Limited parking space is a problem at Ruck-a-Chucky. Existing pit toilets are not sufficient to service the entire area. Driver's Flat Road, a steep, narrow and rough dirt road, becomes slippery when wet, often necessitating closure during the rainy season. Four wheel drive vehicles are often stuck here.

3) Cherokee Bar. - The Cherokee Bar area is located across the Middle Fork, on the south bank, and downstream from Ruck-a-Chucky. The wide gravel bar is one of the few flat areas in the upper section of the Middle Fork canyon. Cherokee Bar is accessed via the dirt Sliger Mine Road, which leads down into the canyon from SR 193 at Georgetown. The road is narrow, steep, and rough enough to discourage most potential users with passenger cars. Since most boaters use the Ruck-a-Chucky area as a take-out, the primary uses here are day users and campers engaging in activities such as fishing, hiking, nature study, and recreational gold mining. Because of the absence of heavy boating activity, Cherokee Bar is a more peaceful, secluded area.

As with many of the other water oriented use areas, Cherokee Bar receives most of its use in July (20%), with 47% of its use occurring in the summer months, and 40% of its use occurring in the spring months and negligible use occurring in the winter months (see Figure H-14). During rainy season, Sliger Road is often slippery enough to necessitate closure.

4) Knickerbocker Flat. - Knickerbocker Flat consists of an approximately 2,000 acre plateau located between SR 49, the community of Cool, and the canyons of the North and Middle Forks of the American River. Knickerbocker Flat was acquired by the USBR in order to serve as the major developed recreation site of the Auburn Dam project. The gently rolling, oak woodlands were to be developed with drive-in campgrounds, picnic areas, visitor center, maintenance facility, concession horse stables, trailheads, and reservoir overlooks. On the edge of the proposed reservoir a major boat launching and parking site would be developed.



Distribution of Attendance
Ruck-A-Chucky Use Area
Contribution to Annual Total
28%
26%
24%
22%
20%
18%
16%
14%
12%
10%
8%
6%
4%
2%
0%
Jan. Feb. Mar. Apr. May Jun. Jul. Aug. Sept. Oct. Nov. Dec.
Based on 1988 Attendance Data

Figure H-13

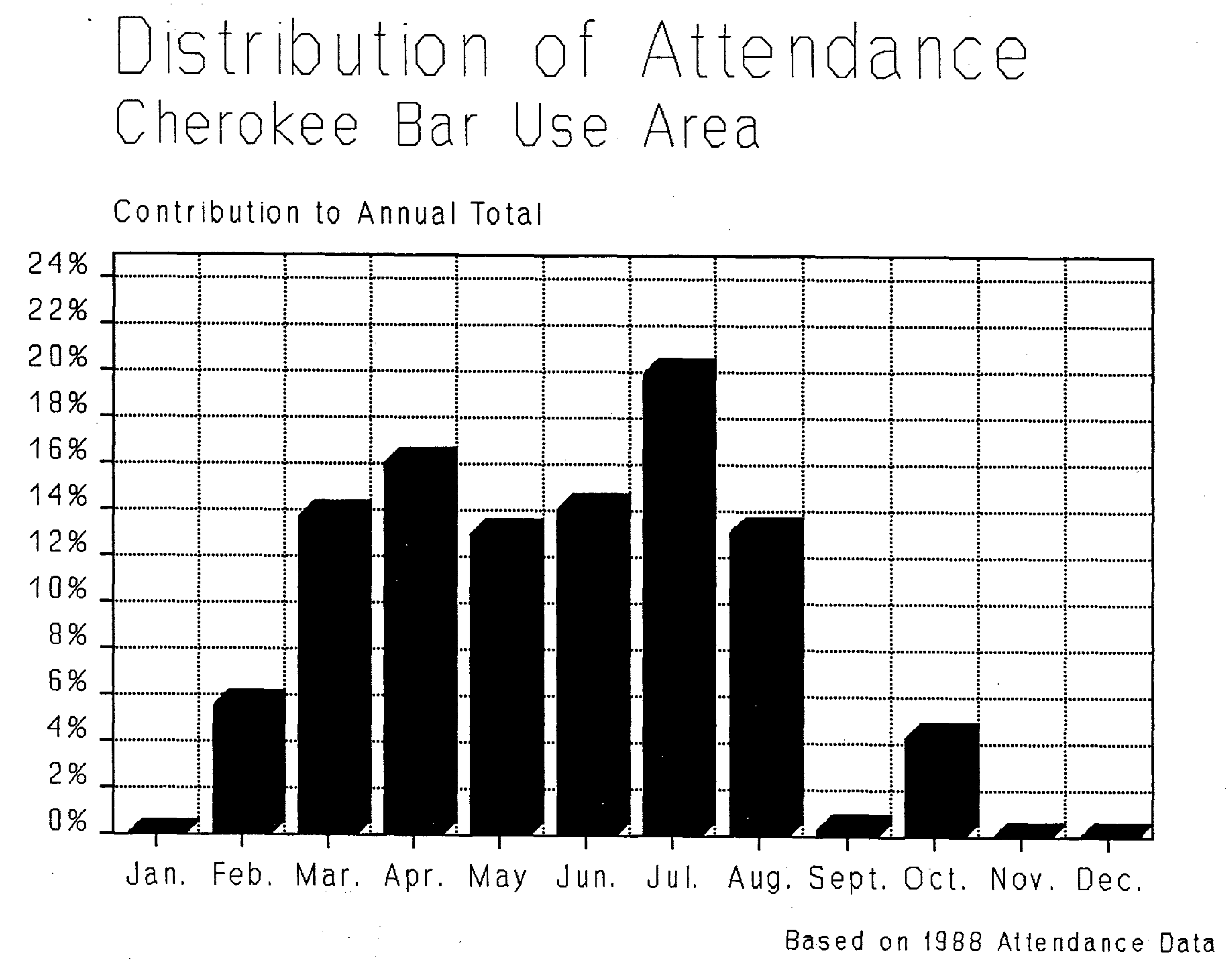

Distribution of Attendance
Cherokee Bar Use Area
Contribution to Annual Total
24%
22%
20%
18%
16%
14%
12%
10%
8%
6%
4%
2%
0%
Jan.
Feb.
Mar.
Apr.
May
Jun.
Jul.
Aug.
Sept.
Oct.
Nov.
Dec.
Based on 1988 Attendance Data

Figure H-14

The Knickerbocker Flat area is visually quite distinct from other lands in the Auburn SRA. Because of its size users can easily move away from views of the rapidly growing community of Cool, and experience the more pristine scenic views and visual diversity of the area which differs greatly from the adjacent canyonlands. For these reasons, and the relatively gently terrain, the area is very popular with equestrians, hikers and runners. The area is articulated by rolling topography and open savanna with ponds bellowing with frogs, narrow riparian woodlands along creek canyons, oak woodland on rolling to moderately steep topography, and pine and oak-studded ridgetops featuring long views into the river canyon. From Panorama Point, spectacular views of Mount Diablo, the Sutter Buttes and the Crystal Range of the Sierra Nevada crest can be seen.

Knickerbocker can currently only be accessed on foot or horseback, as the area was closed to other public uses during the construction of the Auburn Dam. The major south bank Dam construction access road crosses Knickerbocker Flat and connects with SR 49 at Cool. The current trailhead parking area is located off of SR 49, behind the Cool Fire Station. Except for the two very popular hiking and equestrian trails which lead from the trailhead down to the Confluence area, recreational use of Knickerbocker is quite limited due to the current closure. Nearly the entire area is leased for cattle grazing, and radio broadcast antennas have been constructed on a BLM land parcel. Another portion of the property is being used by an elementary school for a playground.

5) Foresthill Divide. - The Foresthill Divide area occupies the ridgetop between the North and Middle Forks of the American River. Along with Knickerbocker Flat, the Foresthill Divide is the only other area of Auburn SRA with ridgetop lands. Like Knickerbocker, the area's hilltop location gives it high scenic quality and spectacular views. The USBR acquired the lands in this area to prevent private development from degrading the visual quality of the future reservoir and it surroundings. The steep and broken hills in this area divide the views from the Foresthill road into pockets of chaparral, pine and oak thickets, and grassy clearings punctuated by long views into and around the river canyon. Thus Foresthill Road, through the Foresthill Divide, provides a very scenic route. There is little trail development on the Divide and few (approximately 40) parking spaces on pullouts along the length of the Foresthill Divide Road. Because of the lack of trail and parking development, most of the ridge is secluded and provides a peaceful environment for the few users who do venture off the road. The steep terrain of the off-road portions of this area limits use to persons in reasonable or good physical condition.

CHAPTER III - RECREATION NEEDS AND OPPORTUNITIES

The lower American River, Folsom Lake, and upper American River Canyons provide prime and unique resources for outdoor recreation opportunities. The lower river is officially designated as a "recreational river" within both the State and Federal wild and scenic river systems. Adjoining the lower river in Sacramento is the American River Parkway, a 5,000-acre greenbelt used by an estimated 5 million visitors each year. Over 2.8 million people, including over 900,000 in Sacramento County (1980 census) reside within a 100-mile radius from Sacramento. These areas, because of their location, large surrounding population, and expected population growth nearby, have a great potential for increased recreation demand.

In 1987, the CDPR prepared a report "Public Opinions and Attitudes on Outdoor Recreation" which surveyed State-wide, the publics participation in and opinion concerning 38 recreational activity types in California. The report quantified uses, unmet demands for these activities, and gauged public support for providing the activities. Finally they assigned a needs assessment priority for use in planning future recreation developments. The results of this survey for those activities applicable within the study area are displayed in Table H-7. Many of these activities are also those with the greatest demand as indicated by the needs assessment priority ranking (walking, hiking, beach use, cycling, nature study, picnicking, and camping). Other results of this survey found that nature oriented parks or preserves and back country natural areas are the two types of areas most preferred by Californians.

The city and county of Sacramento have identified similar priorities for recreation land and facility development in their respective long-range master plans. Of particular concern with the rapidly expanding area population is the need for open space areas that preserve important natural values of the landscape.

Within the Sacramento Metropolitan Area, the American River Parkway is the most significant recreation resource. It is also recognized nationally as an outstanding example of an urban parkway. However, the popularity of the parkway and the Jedediah Smith bicycle trail results in highly intensive use, often to the point of exceeding a safe capacity. Additional recreation trails, especially ones along "natural" appearing areas such as the NEMDC would assist in providing relief for crowding of the existing trails and meet local open space goals.

Significant flat water boating opportunities area present on nearby rivers and reservoirs (Sacramento and American Rivers, Lake Natoma, and Folsom Reservoir). Additional opportunities for

Table H-7

CDPR Recreation Needs Public Survey Results

Activity	Avg Days For Participant	Est. Household Participation Days (millions)	Latent Demand Rating	Public Support Rating	Needs Priority Assessment
Walking	40.6	149.6	hi	hi	1
Beach Use	16.7	69.0	hi	hi	1
Cycling	11.1	46.0	hi	hi	1
Swimming	10.9	42.6	mod	mod	4
Nature Study	10.5	31.5	hi	hi	1
Picnicking	9.5	31.6	hi	hi	1
Camping (Composite)	8.0	26.5	hi	hi	1
Fishing	6.9	19.5	hi	mod	3
Hiking	3.6	14.8	mod	mod	4

this type of recreation exist within a one-hour travel radius of the Sacramento metropolitan area. These include upstream reaches of Comanche Reservoir, Lake Berryessa, Jenkinson Lake and Union Valley Reservoir.

Less plentiful recreation opportunities are presented by the rugged foothills, mountains, and canyons of the upper American River area with their associated whitewater boating activities. The North, Middle, and South forks of the American River present this desirable combination in close proximity to a major urban area. Activities on the South Fork for river oriented hiking, camping, picnicking, and wading are restricted due to the large amounts of private ownership. The nearest other free-flowing reaches of major rivers in a similar secluded setting are the Tuolumne (100 miles to the southeast) and the Middle Fork of the Feather River (75 miles north). The Stanislaus River (75 miles to the southeast) has a stretch of free-flowing water, but is in a low foothill and valley setting and is rapidly experiencing urban development.

CHAPTER IV - RECREATION PLAN FORMULATION

The Federal Water Project Recreation Act of 1965 provides for recreation to be considered as a full project purpose at Federal water resources projects. A non-Federal sponsor must participate in the study and construction of the recreation facilities and assume all operation and maintenance responsibilities of the completed project. The development of recreation facilities is restricted to existing project lands and features, with some additional lands provided if required for access, parking, and provision of sanitary or other health and safety facilities.

A June 1989 letter was sent to state and local agencies having the potential for participating in recreation development to determine if there was any interest. This letter was followed up with a meeting of potential recreation sponsors to discuss recreation opportunities within the American River Watershed Investigation study area, to explain Federal constraints on recreation development, and to gauge local interest. Considerable interest was expressed by many of the agencies for including recreation features in the American River Watershed Investigation. However, only the Sacramento County Department of Parks and Recreation and City of Sacramento Department of Parks and Community Services had potential projects identified and were willing to cost share in the development and construction of the facilities. The California Wildlife Conservation Board is not able to participate in planning of facilities but has a program of funding for other agencies projects which contribute to access for fisheries and wildlife recreation areas. Because of the uncertainty associated with identifying what facilities would be constructed at the USBR Auburn dam site, if any, and current planning underway for interim recreation development of these lands, no interest was expressed at this time for addressing recreation development in these areas.

Subsequent coordination meetings and field visits between the Corps and the City and County of Sacramento identified several potential areas of recreation development. These include development of hiking, bicycling, and equestrian trails along the NEMDC with connectors along Dry and Arcade Creeks, trail development along the Sacramento River levees (Garden Highway and the Pocket areas), river access, and passive wildlife habitat enhancement.

The trail development and associated facilities in Natomas are included in the development of project alternatives. These facilities would be located on existing project easement lands and are in the vicinity of proposed construction for the American River Watershed study. The recreation features are discussed in more detail in the next section.

Because the American River Watershed project does not include any work on the existing Sacramento River levees, the Garden Highway and Pocket trails are not considered in this study. These trails were considered for inclusion in the ongoing Sacramento Urban levee rehabilitation work to bring the Sacramento Flood Control levees back to design standards. However, because the recreation design process could not keep up with the levee work, it was not carried out with the levee fixes. Because of the high demand for these types of facilities, these trails will likely be investigated further in the future under the existing recreation authorities of the Sacramento River Flood Control Project.

There is one surface street crossing on the Jedediah Smith bike trail at Del Paso Boulevard. This is a heavily traveled road and at times is dangerous for cyclists to cross. For safety reasons the existing surface street crossing of the Jedediah Smith at trail be closed and the trail rerouted beneath Highway 160 and around the mobile home park to avoid the need for street crossings.

7. General. - The primary recreation features in Natomas would include paved pedestrian/biking trails (9.5 miles) and unpaved equestrian trails (7.5 miles) along portions of the NEMDC and lower Dry Creek and Arcade Creek (see plate 27). The trail system will be located entirely off-street, utilizing overpasses and underpasses to avoid surface crossings of arterial streets wherever possible. Additional minor connector trial segments will be developed to link the trails to the adjacent neighborhoods. Existing and planned City and County parks will be utilized as staging areas (parking and restrooms). Shade tree plantings will also be implemented along the NEMDC to beautify and enhance the recreation trail. Finally, for safety reasons a 1.1 mile section of the existing Jedediah Smith Bike trail would be relocated.

The City and County of Sacramento will serve as joint non-Federal sponsors of the NEMDC trail. The proportion of the costs to be borne by each agency will be negotiated between the two participating agencies.

8. Bicycle and Equestrian Trail Design and Siting Considerations. - Trail construction will be located on lands acquired for construction of the Natomas portions of the American River Watershed flood control project or on existing lands that are part of the Sacramento River Flood Control Project. No new lands would be purchased other than that required for access to the trails or to provide for public health and safety.

Unless specified otherwise, all bicycle trails would be constructed with asphaltic concrete over a compacted base course, 12-feet wide with two-foot-wide decomposed granite surfaced shoulders (for runners). A yellow centerline stripe would be provided. Where levee top widths or major obstructions such as large trees would not permit a 16-foot wide trail, the width may be reduced to as little as eight feet, with two-foot shoulders. City and County recreation staff experience with other heavily utilized local trails has found trails with 12-foot widths have significantly lower accident rates.

At all street access points, removable locking bollards would be used to prevent unauthorized vehicle entry and still allow foot and bicycle access.

The bicycle trail alignments will utilize a variety of locations including levee benches (areas of higher ground elevation at the levee toe) and levee crowns to provide the user with a varying and interesting experience when using the trail.

All of these alignments are located high enough above the drainage channels to avoid flooding in all but severe storms (approximately five-year or less frequent flood events). Trail segments which are located within the NEMDC tend to block out the sights and sounds of the surrounding urban development and direct the riders attention to the adjacent water, marshes, trees and wildlife. Trail segments located up on the levee tops provide the users with expansive views out over the adjacent neighborhoods and drainage channel.

Where possible equestrian trails will be located apart from bicycle trails, generally on opposite sides of the creek. The alignment will usually be located at the base of the levees within the NEMDC. This alignment will result in the trail being flooded during portions of the wet seasons. Bridges over the creeks or tributary drainages will not be required -- fords will be utilized. Clearance of native soil, 18- 36-inches in width would be required. Clearance of at least 12 vertical feet would be required under bridges. For the construction of the equestrian trail tread, only the woody vegetation would be cleared, then the tread width would be scarified and disked to expose rocks, metal or other debris on the site, and that debris would be removed. The trail route also would be marked every 500 feet (or less if visibility is limited) with flexible "Carsonite" traffic marker posts denoting the equestrian trail and specifying closure to bicycles and motor vehicles. At rest areas, hitching posts would be provided.

In general the non-Federal sponsors wish to have a minimal level of development. The surrounding area has a high vandalism and crime rate, thus elaborate facilities (except for those with controlled entry) are not desired. Basic trails, with trash containers, occasional picnic tables, shade trees, and drinking fountains will be the basic recreation trail elements.

Riparian shade tree planting (40% Fremont cottonwood, 20% willow, 20% White Alder and 20% Valley Oak) will be included along existing barren sections of the NEMDC. Oaks would be planted only on the slightly higher trail bench slopes. Due to Sacramento's extremely hot summer temperatures, and predominantly clear skies, shade trees are essential to providing a quality recreation resource. The low flood flow velocities, and ample capacity of the NEMDC allow trees and shrubs to remain in the channel without compromising the channel flood flow capacity. Trees would only be planted on the channel floors or bench slopes, not on levee slopes. This planting is close to the surface on the channel floor. Watering would be accomplished by tank truck, during the first two to three years after planting. Tree planting would not occur along the Arcade or Dry Creek trails, as flood flows would be restricted by the vegetation.

9. <u>Real Estate Costs</u>. - The levees and channels of the

NEMDC, Arcade Creek, and lower Dry Creek, are held in easement by the local reclamation and flood control districts as part of the existing Sacramento River Flood Control Project. The adjoining private land parcels actually extend out under the channels and levees. For a public recreation trail corridor, full fee title or a recreation easement would be required. The cost applicable to the recreation plan are the difference between the existing flood control easements and fee purchase or the cost of a recreation easement. This would be included in the 50% cost sharing agreement. Costs associated with the minor separable lands required for trail access and necessary health and safety facilities are also applicable to the non-Federal 50% cost sharing requirement. Relocating the bike trail will be done on County land, no land costs are attributed to the recreation plan for these lands which are already flooded as part of the existing flood control system.

10. Detailed Plan Description.

a. Equestrian Trail Description. - This feature consists of a 7.5 mile system of cleared dirt trails extending from the existing equestrian trail in the American River Parkway north along the NEMDC to Elkhorn Boulevard (5.5 mi.) with a spur trail (2 miles long) along Dry Creek to the existing Sacramento Northern Trail. On the south end of the trail, the existing staging areas on the American River Parkway would be utilized for the connecting NEMDC trail. A water trough (self-filling guzzler) would be developed at the junction with the American River Parkway. The trail would follow the base of the existing Sacramento River Flood Control Project levee up to Arcade Creek. Between Arcade Creek and Main Avenue the existing levee will be raised and widened on the channel side. The equestrian trail will follow the base of the new levee work.

At Main Avenue a new bridge will be constructed. The equestrian trail will cross under the bridge and then cross the NEMDC and continue north along the base of the west levee roughly paralleling the pedestrian/bike path. On the north end of the trail, south of Elkhorn Boulevard, the trail would cross back to the east side of the NEMDC to a new staging area on the east side of the NEMDC. A 20-space, crushed rock surfaced parking area and equestrian staging area would be constructed. Sufficient room would be provided for turning and parking horse trailers. A drinking fountain, hitching rack and shade tree plantings would also be provided. A water trough (self-filling guzzler) would be developed at this staging area.

At Main Avenue, the trail would ramp up the levee north of Main Avenue and parallel the Bike trail to cross the UPRR tracks at the grade crossing. On the east side of the UPRR tracks, a right of way would be purchased to allow the trail to turn north and ascend an 8% ramp to the crest of the south levee of Dry Creek. The equestrian trail would then ramp down to the base of the levee and would follow the base of the existing and proposed levee to Rio Linda Boulevard. The trail would cross Rio Linda Boulevard and a new 200-foot right-of-way would be purchased to tie into the existing Sacramento Northern Trail.

b. <u>NEMDC Pedestrian/Bicycle Trail Description</u>. - This feature consists of a 9.5 mile system of paved pedestrian/bicycle trails extending north from the American River Parkway trail (via the Sacramento - Northern Trail) along the NEMDC to Elkhorn Boulevard (5.5 mi.), with spur trails approximately two miles in length extending east along lower Arcade Creek, and lower Dry Creek. The southern terminus of the trail would be located on the NEMDC east levee, where the City's Sacramento Northern Trail leaves the NEMDC levee and continues northeast across the Union Pacific Railroad (UPRR) tracks. The proposed trail would descend off the levee top on a 8% ramp (fill material on the channel side of the east levee), to the existing high ground areas on the channel bottom (levee bench). A short segment of reduced width trail may be required to pass by several large trees. The trail would continue north on this bench under the West El Camino Bridge. Between the ramp and the El Camino Bridge approximately 50 shade trees would be planted along the trail.

At El Camino Avenue, a ramp would be provided on the south side of the bridge to provide access to the southside sidewalk. The trail would continue under the El Camino Bridge and cross the channel north of the bridge on fill material with box culverts to allow normal drainage. On the west levee the trail would climb up the levee slope to the top of the levee. A short section of the levee top would be paved to provide access to the north sidewalk of the El Camino Bridge. The portion of the levee from El Camino to Main Avenue will be raised an average of a half a foot.

On the west bank of the NEMDC (north of West El Camino), the paved trail would follow the top of the levee (on the maintenance road) northward to a point approximately 500 feet north of Gardenland Park. At the end of Peralta Avenue, a trail access ramp down the land side of the levee would be provided to provide access off the levee top. The existing Gardenland Park parking, restrooms, drinking fountains and picnic sites would be co-utilized by the trail. Approximately 800 linear feet of four-foot high safety railing would be installed along the west edge of the levee top to discourage persons from short-cutting down the levee side and eroding the levee slopes.

At the point approximately 500 feet north of Gardenland Park, the trail would descend off the levee top to an existing earthen bench located on the eastside of the west NEMDC levee. This point would also serve as western abutment of a second fill crossing of the NEMDC to the east side of the channel at Arcade Creek. Box culverts would be provided to maintain normal flows in the channel.

The trail would continue northward on the NEMDC west levee bench to a point approximately 1,000 feet south of the I-80 bridge, where it would climb a 8% fill ramp back up to the levee top. Approximately 250 shade trees would be planted along the trail in this segment adjacent to the trail. Another street access fill ramp would be provided at the end of Patio Avenue to provide community access.

As mentioned above, at the point approximately 1,000 feet south of I-80, the trail would climb back up on the levee top, and follow the levee top to a point approximately 800 feet north of the I-80 bridge, where a 8% fill ramp would return it to the earthen bench alignment. The trail would follow this bench to, and under, the Main Avenue bridge which is to be replaced by the flood control project. Between I-80 and Main Avenue, another 300 shade trees would be planted along the trail. Mid-way between I-80 and Main Avenue, at the City storm drain pump station, a fill ramp would be constructed up and over the levee, to provide trail access out onto Northgate Boulevard.

At the Main Avenue bridge, the trail would loop up the levee on the north side to gain access to the north sidewalk, which would provide access to the Dry Creek spur trail. The NEMDC trail would continue north along the bench to Elkhorn Boulevard. Additional earth fill would be required in several locations where the bench is incomplete or too narrow to support the trail. About 2,400 feet of fill approximately 8 feet wide and 2 feet deep would be required north of the pumping facility at Ascot Road and about 600 feet of fill would be required in an area approximately 1000 feet south of Elkhorn Boulevard. At the end of Sorento Road, a fill ramp would be provided for street access. Approximately 300 shade trees would be planted along this segment of the trail.

c. Dry Creek Trail. - A 12-foot sidewalk would be provided on the north side of the new Main Avenue bridge to safely accommodate the Dry Creek trail traffic. On the east side of the bridge, the trail would continue parallel to Main Avenue and cross the UPRR tracks at the Main Avenue grade crossing. On the east side of the UPRR tracks, a right-of-way would be purchased to allow the trail to turn north and ascend an 8% ramp to the crest of the south levee of Dry Creek. From there the trail would follow the existing and proposed levee crests to Rio Linda Boulevard. The trail would cross Rio Linda Boulevard and a new 200-foot right-of-way would be purchased to tie into the existing Sacramento Northern paved trail.

d. Arcade Creek Trail. - The Arcade Creek trail would cross under the UPRR tracks at the base of the north Arcade Creek levee and then slope up to the top of the levee and follow the levee top eastward. Due to the narrower width of the Arcade Creek levees, a less than 12-foot wide trail may be constructed. Near the confluence, one home and lot or, if possible, one vacant lot would be purchased to provide access out to Olmstead Drive in the Strawberry Manor neighborhood. Only a landscaped trail corridor with side security and privacy fences would be provided at this access point, no parking would be developed. An equestrian trail would not be provided along Arcade Creek.

The Arcade Creek trail would cross under Norwood and Rio Linda Boulevards on the channel side of the levees. Between these two arterials, the trail would intersect with the existing Sacramento Northern trail. The proposed Arcade Creek trail would terminate on Rivera Drive, at the west edge of Haggenwood Park (the restricted space between the ballfields and the creek prevent the trail from continuing eastward to Marysville Boulevard).

11. Rerouting of the Jedediah Smith Recreational Trail. - To the west of Highway 160, the existing bike trail crosses a busy section of Del Paso Boulevard creating a safety problem for trail users. To avoid the safety problems the trail would be rerouted starting approximately 400 feet east of the Highway 160 overpass. It would go south to the river where it would pass under the Highway 160 bridge and be routed around the trailer park to the west of the bridge and rejoin the bike trail about 400 feet west of Northgate Boulevard. The total length of trail is approximately 1.1 miles.

CHAPTER VI - RECREATION PROJECT COSTS AND BENEFITS

12. Recreation Costs. - The estimated first cost of the recreation features is approximately $1.4 million dollars (see Table H-8). Total annual costs including operation and maintenance of the facilities are estimated at $890,000. A detailed cost estimate is presented the Design and Cost Estimates.

Table H-8

Recreation Costs

Item	Cost
Recreation Features	$1,400,000
Lands	6,770,000 1/
Environmental Mitigation	0
Engineering, Design, Supervision, & Administration	610,000
Subtotal	$ 8,780,000
Average Annual Equivalent Costs	$ 790,000
O&M	100,000
Total Annual Costs	$ 890,000

1/ Includes land and acquisition costs.

13. Recreation Benefit Analysis. -

a. Recreation Demand. - The Sacramento Metropolitan area has a great unmet need for trail and stream oriented recreation. The city and county of Sacramento and State of California Department of Parks and Recreation plans all indicate that there is a situation in the study area where all high quality recreation features in these categories are being used at or above the carrying capacities. Many popular recreation features are filled to the point of overcrowding during summer weekend periods.

Tables H-9 through H-11 show a derivation of the existing recreation demand within the project market area (Sacramento Metropolitan Area). Demand information was estimated using per capita recreation use data for the State of California and applying it to the market area population. This was done for each of the major types of recreation uses expected in the study area (see Table H-9). Statewide information on the average user-days per participant and total number of annual user-days in California are listed for each activity. The per capita use rate for each activity was estimated using the 1987 State population estimate.

Table H-10 presents a breakdown of the per capita use for each recreation activity by the type of area in which the recreation activity is expected to take place; i.e., developed trail use, developed park areas, other non-park sites (street use, undeveloped property). These factors are estimates based on professional knowledge of existing recreational activity within the market area and comparison to data for other major metropolitan areas.

TABLE H-9

SELECTED CALIFORNIA PER CAPITA RECREATION RATES

Activity	Average days use per Participant	Statewide Use Million Days	Per Capita Rate *
Walking	41	149.6	5
Beach	17	69.0	3
Cycling	11	46.0	2
Swimming	11	42.6	2
Nature Study	11	31.5	1
Picnicking	10	31.6	1
Camping	8	26.5	1
Fishing	7	19.5	1
Hiking	4	14.8	1

Based on 1987 estimated population of 27,217 people.

TABLE H-10

ESTIMATED ALLOCATION OF DEMAND IN SACRAMENTO MARKET AREA

Activity	Per Capita Use Rate	Trail Use Rates	Park/Recreation Use Rate	Non-Park Site Use
Walking	5	1.5	.5	3.0
Beach	3		1.0	2.0
Cycling	2	.6	.2	1.2
Swimming	2	.1	.9	1.0
Nature Study	1	.1	.3	.6
Picnicking	1		.2	.8
Camping	1		.4	.6
Fishing	1	.1	.3	.6
Hiking	1	.3	.1	.6

TABLE H-11

MARKET AREA RECREATION DEMAND

Part of Market Area	Population	Recreation Days Trail Demand	Recreation Days Park Demand	Recreation Days Other Demand
Arden Arcade	11,431	34,300	45,700	114,300
Central Sacramento	35,126	105,400	140,500	351,300
East Sacramento	36,976	110,900	147,900	369,800
North Sacramento	36,397	109,200	145,600	364,000
East Broadway	39,898	119,700	159,600	399,000
Other Portions of Market Area	127,113	381,300	508,500	1,271,100
Total Market Area	286,941	860,800	1,147,800	2,869,500

TABLE H-12

MARKET DEMAND FOR TRAIL BASED ACTIVITIES AND PARK ACTIVITIES IN MARKET AREA

Part of Market Area	Population	Walking, Cycling, & Hiking	Other Trail Activities	Park Activities
Arden Arcade	11,431	27,400	6,900	45,700
Central Sacramento	35,126	84,300	21,100	140,500
East Sacramento	36 976	88,700	22,200	147,900
North Sacramento	36,397	87,400	21,800	145,600
East Broadway	39,898	95,800	23,900	159,600
Other Portions of Market Area	127,113	305,100	76,200	508,500
Total Market Area	286,941	688,700	172, 00	1,147,800

By applying the per capita recreation use data to local populations, the recreation demand within the market area for the major trail and park recreation types are calculated and presented in Table H-11. Table H-12 breaks out the market area demand into the major trail and park based activities.

b. Recreation Use. - Table H-13 provides an estimate of the amount of existing use found in the undeveloped drains and creek channels for the portions of the project area proposed for recreation development today, and the expected increase in use of these areas over the project's economic life. Also shown is the anticipated use of these areas if the proposed project facilities are constructed. Estimates are based on 1987 use surveys of similar central California recreation areas and 1989 and 1990 use-data for the American River Parkway facilities. These samples were adjusted using factors developed from similar central California recreation areas to estimate annual recreation use. Subtracting the estimated existing use without the project from the use with developed facilities in place, provides an estimate of the new recreational use that would be obtained from providing the proposed recreation facilities.

TABLE H-13

SUMMARY OF ESTIMATED ANNUAL RECREATION USE

REACH/ALTERNATIVE	EXISTING RECREATION USE Without Project Use		POTENTIAL RECREATION USE With Project Use		ESTIMATED NET Increase in use	
	Annual Recreation Days		Annual Recreation Days		Increase In Annual Recreation Days	
	YEAR 1	End Year	YEAR 1	End Year	YEAR 1	End Year
NEMDC Trail	1,400	1,700	81,800	102,300	80,400	100,600
Dry Creek Trail	500	700	54,600	68,200	54,100	67,500
Arcade Creek Trail	800	1,000	81,800	102,300	81,000	101,300
Jedediah Smith Trail	109,100	136,400	163,700	204,600	54,600	68,200
Totals	111,800	139,800	381,900	477,400	270,100	337,600

When recreation demand is compared to existing recreation use in the study area it is seen that there is a significant unmet need for recreation opportunities. Recreation that is occurring in this area is primarily on existing American River parkway facilities. But significant use is being made of undeveloped areas on the NEMDC canal and tributary creeks. Developed recreation facilities in these areas with the project would both improve the value of existing recreation experiences and provide new recreation opportunities to meet the identified area demand.

c. Recreation Benefit Analysis. - Estimates of the recreation day use value for the existing unimproved recreation activities in the study area and for the recreational activity expected with the new facilities is provided in Table H-14. The recreation day-use values were determined according to procedures outlined in ER 1105-2-100 (Planning Guidance; Chapter 6, Economic Considerations; Section VIII, NED Benefit Evaluation Procedure: Recreation).

TABLE H-14

GENERAL RECREATION UNIT DAY VALUES

Value Per Recreation Day		
	Existing (Unimproved)	**With New Facilities**
NEMDC Trail	$3.00	$4.01
Dry Creek Trail	3.00	4.78
Arcade Creek Trail	3.00	4.78
Jedediah Smith Trail	5.16	6.32

Using the day-use recreation values Table H-14 and average annual recreation use derived from Table H-13, the recreation benefits were calculated. Benefits for new recreation use were obtained using the net increase in recreation use in the project area and the day-use value of the developed recreation facilities. An additional benefit for increasing the value of the existing unimproved recreation use was also calculated. It is assumed those people already using the project area would continue to do so, but the new facilities would make the recreation experience more valuable. The project benefit of that existing recreation is the difference between existing recreation values and developed recreation values shown in Table H-14. Table 15 displays these benefits. The average annual values were calculated using a 8 3/4 % interest rate and a 100-year period of analysis.

The proposed recreation developments are expected to provide in excess of 335,000 user days annually at a value of approximately $1.6 million annually. This results in a project benefit-to-cost ratio of 1.0.

TABLE H-15

RECREATION BENEFITS

	Value of Increase	Change in Value for Existing	Total (Average Annual)
NEMDC Trail	$ 368	$ 3	$ 371
Dry Creek Trail	277	3	280
Arcade Creek Trail	440	3	443
Jedediah Smith Trail	360	116	476
Total	$1,445	$ 125	$1,570

CHAPTER VII - RECREATION IMPACTS FROM REOPERATION OF FOLSOM DAM AND RESERVOIR

14. Introduction. - Permanent reoperation of Folsom Reservoir would result in impacts to recreation at Folsom SRA and in the lower American River Parkway. Reoperation would result in reduced water elevations in the reservoir and alteration to the flows in the lower American River. This chapter briefly describes the analysis of these impacts.

15. Folsom Reservoir. - Water surface elevations at Folsom Lake directly influence the recreational quality of the resource, which in turn affects both attendance and user behavior patterns. Table H-16 presents the changes in water surface elevations with varying levels of flood control storage. Figure H-15 shows this information in a visual format. The extent to which the resource is affected, and the quantitative impacts, vary from month to month. The main recreational use season, May through August, is most sensitive to water surface elevations because of the high use during this period. Use patterns during the winter months are not as dependent on water surface elevations because much of this use is not directly water dependent. Additionally, recreation use during the winter season is significantly lower than the main recreation season, which accounts for approximately 67 percent of the annual use.

Impacts to recreation at Folsom Reservoir due to water surface elevation fluctuations were developed using information provided by DPR. The DPR staff identified the main recreational activities associated with Folsom Reservoir and determine the use areas which best reflected unit-wide-use. These areas represent the full range of facility development and recreation use patterns found around the lake. They are:

Beals Point	Browns Ravine
Dike 8	Granite Bay
Peninsula	Rattlesnake Bar

For each of the areas use-stage curves were developed that reflected (1) use patterns by use area, (2) seasonal use pattern changes, and (3) changes in use levels relative to lake water surface elevations. The six use area use-stage curves were combined to represent reservoir-wide recreational activity at various stage levels. Attendance was projected form the base year to the year 2000 and is expected to increase to 3.44 million. The annual attendance numbers were broken down to monthly estimates and weighted accordingly to the percentage of occurrence for given water year classifications. The USBR operations study for Folsom Reservoir was used as a base to determine water surface elevations for the base condition and the

TABLE H-16

FOLSOM RESERVOIR
AVERAGE END-OF-MONTH SURFACE ELEVATIONS

AVERAGE YEARS												
ALTERNATIVE	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP
400	415	408	411	413	420	429	441	453	450	439	429	420
590	408	398	391	394	405	418	434	448	446	435	425	415
650	406	393	385	387	398	413	431	446	445	433	423	414
WET YEARS												
ALTERNATIVE	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP
400	420	415	422	424	429	437	450	465	465	457	449	443
590	414	405	400	402	413	428	446	465	466	466	468	442
650	410	399	391	393	405	423	444	464	466	465	468	442
ABOVE NORMAL YEARS												
ALTERNATIVE	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP
400	406	399	398	406	417	427	447	464	463	450	439	432
590	400	389	381	390	403	419	444	463	462	447	434	427
650	398	386	378	387	397	415	441	463	462	446	433	426
BELOW NORMAL YEARS												
ALTERNATIVE	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP
400	422	414	414	414	427	437	448	458	455	443	431	422
590	415	403	394	394	411	427	442	453	451	438	428	418
650	413	398	387	387	403	422	439	451	449	436	426	416
DRY YEARS												
ALTERNATIVE	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP
400	411	405	411	414	422	431	439	448	444	430	418	407
590	399	390	392	397	403	422	428	438	434	421	408	396
650	397	385	385	389	396	416	423	434	431	418	405	394
CRITICALLY DRY YEARS												
ALTERNATIVE	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP
400	409	399	396	396	396	402	407	409	405	393	380	367
590	399	389	382	380	382	389	393	398	394	380	370	356
650	398	385	376	374	376	384	390	396	393	380	370	358

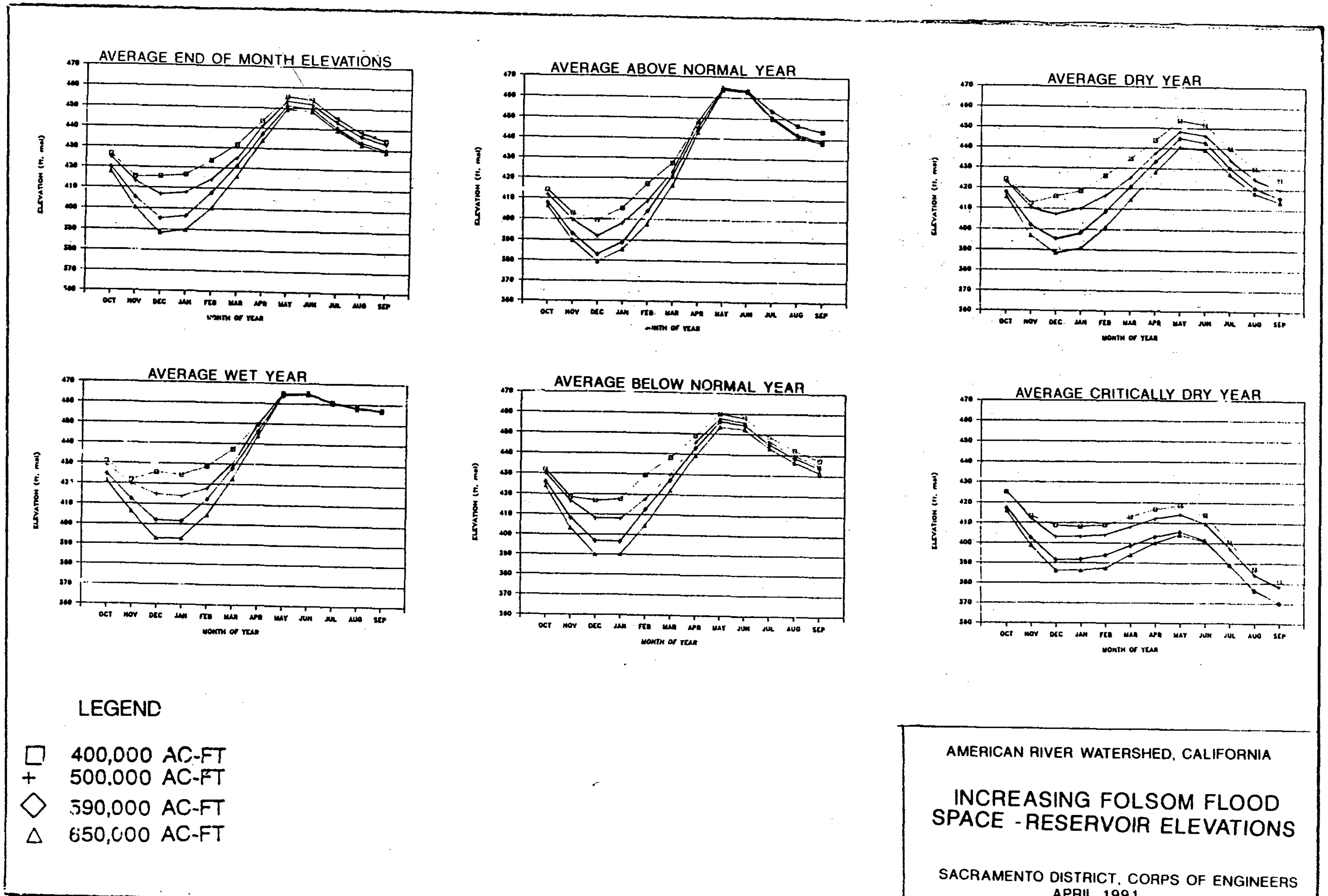

AVERAGE END OF MONTH ELEVATIONS
AVERAGE ABOVE NORMAL YEAR
AVERAGE DRY YEAR
AVERAGE WET YEAR
AVERAGE BELOW NORMAL YEAR
AVERAGE CRITICALLY DRY YEAR
ELEVATION (ft. msl)
MONTH OF YEAR
OCT NOV DEC JAN FEB MAR APR MAY JUN JUL AUG SEP
LEGEND
400,000 AC-FT
500,000 AC-FT
590,000 AC-FT
650,000 AC-FT
AMERICAN RIVER WATERSHED, CALIFORNIA
INCREASING FOLSOM FLOOD SPACE - RESERVOIR ELEVATIONS
SACRAMENTO DISTRICT, CORPS OF ENGINEERS
APRIL 1991

Figure H-15

590,000, and 650,000 ac-ft reoperation scenarios. Estimated attendance changes associated with water surface elevation for the base elevation and each of the reoperation scenarios are presented in Table H-17.

The reservoir is highly rechargeable due to the inflow from the South, Middle, and North Forks of the American River. Because of this, as water surface elevations are drawn down during winter months for flood control purposes, spring runoff and precipitation will generally refill the reservoir. While the main recreation season elevations may be lower as a result of the reoperation drawdown, they remain within the range of good to excellent for recreation during the main recreation season. Dry and critical water years are more significantly impacted by the drawdown regimes.

Winter water surface elevations resulting from each reoperation regime are not as optimistic. Since completion of the Mormon Island Dam stabilization work, mooring at Browns Ravine Marina would be possible almost year-round on average

TABLE H-17

FOLSOM RESERVOIR REOPERATION
ANNUAL CHANGE IN RECREATION USE

Activity	590 000 ac-ft	650.000 ac-ft
Swimming (designated	42,900	85,500
Camping	4,400	5,700
Windsurfing	8,300	9,200
Picnicking	24,100	27,100
Fishing	48,200	83,400
Boating (launch)	110,400	159,300
Boating (non-launch)	5,500	[5,300] [1]
Jet Skiing	12,400	16,200
Swimming (non-designated)	20,500	11,500
Berthing	12,600	14,200
Equestrian	1,200	2,100
Boat Camping	1,500	2,000
Hiking	100	100
Special Events	0	0
Net Decrease	292,100	411,100

[1] Bracketed numbers represent an increase in use.

for normal reservoir operations. The 650,000 ac-ft drawdown scenario, results in the loss of year-round boat mooring at Browns Ravine Marina. The marina is expected to be operable only from April through July on average. A threshold elevation of 410 feet is necessary to maintain mooring and is also necessary to utilize the main boat ramps.

To estimate the economic losses associated with reduced recreation usage at Folsom reservoir, the net recreational use losses were multiplied by an average user day value of $5.70. Economic losses for reservoir recreation are estimated at $2.3 million annually for the 650,000 ac-ft storage alternative. Additionally, entrance fees of $4.00 per car for general recreation, $2.00 per boat trailer, and $10.00 per car for camping are charged. Table H-18 estimates the lost revenues to the DPR from reoperation. The figures assume 3.4 people per car and that all visitations pay the entrance fees.

TABLE H-18

FOLSOM RESERVOIR REOPERATION
DPR REVENUE LOSSES

Activity	590.000 ac-ft	650.000 ac-ft
Swimming (designated)	$ 50,500	$ 100,600
Camping	12,900	16,800
Windsurfing	9,800	10,800
Picnicking	28,400	31,900
Fishing	85,100	147,200
Boating (launch)	194,800	281,100
Boating (non-launch)	6,500	[6,200] 1/
Jet Skiing	14,600	19,100
Swimming (non-designated)	24,100	13,500
Berthing	14,800	16,700
Equestrian	1,400	2,600
Boat Camping	2,600	3,500
Hiking	100	100
Special Events	0	0
Net Decrease	$ 445,600	$ 637,700

1/ Bracketed numbers represent an increase in use.

16. Lower American River

a. General. - The principle water-dependent recreation activities on the lower American River that would be impacted by changing flows from reoperating Folsom Dam and Reservoir are boating (including rafting, kayaking, and canoeing), and swimming and wading. The USBR models provide data with which to determine impacts on critical or threshold flows for these activities based on operating plans for 650,000 ac-ft of flood control storage space in Folsom Reservoir and the year 2020 water use projections. Model flow data is in terms of average total monthly volume released into the lower river at Nimbus Dam. The total monthly volume data from the model was converted to average monthly flow data. This information is provided in Table H-19 and shown in Figure H-16. Studies conducted for the East Bay Municipal Utility District identified minimum flows necessary to support all forms of boating (kayaking, rafting, & canoeing) on the lower American River as 2,000 cfs. Minimum flow required to support wading and swimming recreation is 1,500 cfs.

b. Boating Impacts. - Approximately 90 percent of the annual boat and raft rental on the lower American River occurs between Memorial Day and Labor Day, or roughly June to August. One third of the boating activity is assumed to occur in each of those three months. This analysis assumes the same use pattern holds for private boating. It was assumed that if the Nimbus releases were below the threshold flows required for successful boating, all days for that month, or one-third of annual total recreational boating use, would be lost. Based upon these assumptions, inadequate flows for boating during any of the peak season months of June to August would result in a significant impact.

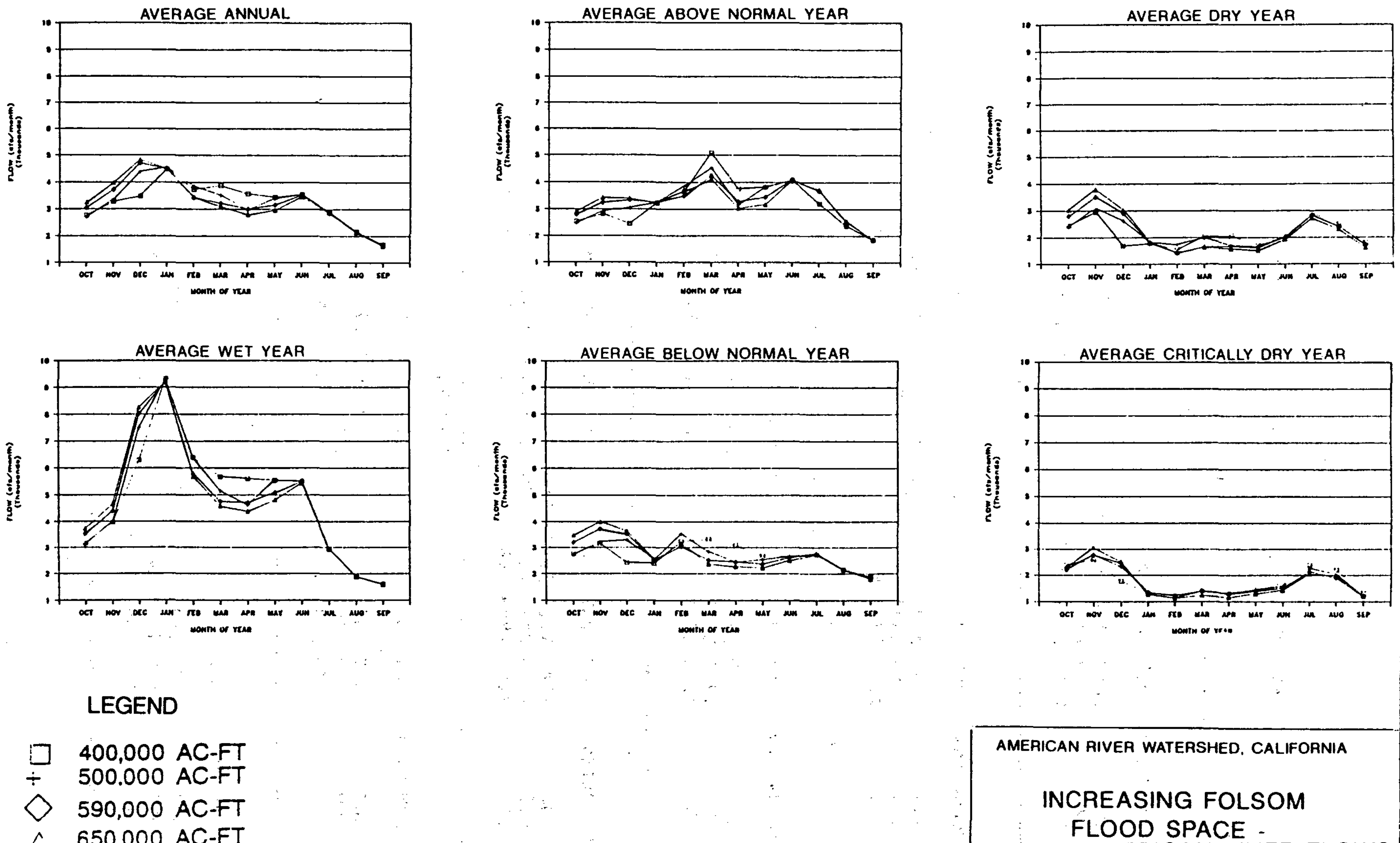
As seen in Table H-19, threshold boating flows are achieved, on the average, for all operating conditions in June and July. However, in August threshold flows are not achieved under either of the reoperation plans or for the base conditions. So while approximately a third of the boating opportunities on the lower American River are expected to be lost as future water supply patterns take effect, no additional adverse impacts to recreational boating are expected from reoperating Folsom Dam and Reservoir to provide increased flood protection.

Looking more closely at the averages for the various water year types, insufficient average flows for boating occur during the month of August in a wet water year scenario under the present operation of Folsom Dam and each of the reoperation alternatives. No impacts are anticipated in above normal years. In a below normal year sufficient boating flows are not available in August under all operating scenarios. In addition, boating

TABLE H-19

AMERICAN RIVER FLOWS BELOW NIMBUS DAM
(Average CFS/Month)

AVERAGE YEARS												
ALTERNATIVE	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP
400	1640	2430	3070	4170	3600	3580	3220	2960	2920	2410	1840	1540
590	1969	2769	3372	4114	3171	3278	3257	2702	2899	2475	1842	1518
650	2174	3034	3506	4118	3202	3154	3043	2511	2932	2449	1841	1501
WET YEARS												
ALTERNATIVE	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP
400	1760	3100	5610	8500	6130	5440	5220	4920	4680	2860	1890	1590
590	2158	3472	6126	8406	5499	5041	5339	4476	4662	2856	1890	1582
650	2363	3741	6372	8387	5412	4881	4970	4207	4606	2851	1889	1576
ABOVE NORMAL YEARS												
ALTERNATIVE	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP
400	1480	2280	2230	2920	3540	4830	3430	3100	3370	2780	2080	1730
590	1789	2593	2506	2903	3191	4529	3535	2731	3368	3249	2226	1716
650	1921	2784	2569	2899	3362	4417	3296	2459	3338	3304	2266	1731
BELOW NORMAL YEARS												
ALTERNATIVE	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP
400	1640	2220	2150	2240	3120	2800	2590	2230	2100	2330	1930	1670
590	2116	2671	2364	2199	2619	2465	2602	2045	2055	2322	1879	1625
650	2400	2958	2487	2204	2742	2319	2423	1901	1949	2303	1872	1602
DRY YEARS												
ALTERNATIVE	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP
400	1560	2040	1410	1500	1380	1690	1750	1480	1560	2090	1880	1550
590	1939	2456	1693	1468	1051	1345	1715	1424	1572	2103	1875	1517
650	2174	2741	1822	1520	1088	1325	1625	1330	1497	1999	1780	1430
CRITICALLY DRY YEARS												
ALTERNATIVE	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP
400	1630	1820	1340	1190	1080	900	840	860	900	1400	1230	1000
590	1538	1813	1476	1122	972	911	822	816	839	1265	1076	979
650	1674	2108	1543	1126	970	748	696	723	762	1183	1147	994



AMERICAN RIVER WATERSHED, CALIFORNIA

INCREASING FOLSOM
FLOOD SPACE -
LOWER AMERICAN RIVER FLOWS

SACRAMENTO DISTRICT, CORPS OF ENGINEERS
APRIL 1991

Figure H-16

opportunities would be lost during June under the 650,000 ac-ft storage option in Folsom. In a dry year boating opportunities would be lost in June and August for all operating alternatives. Under the 650,000 ac-ft alternative boating opportunities would also be lost for July, in effect losing all boating opportunities for the main recreation season. In critically dry years all boating opportunities would lost for the main recreation season under the base condition and the two reoperation alternatives. Table H-20 summarizes this information.

TABLE H-20

IMPACTS TO WATER DEPENDENT RECREATION ON THE LOWER AMERICAN RIVER
(% of Annual Use effected during June-August Peak Use Season)

Water Year	Alternative	% Loss of Annual Swimming Recreation	% Loss of Annual Boating Recreation
Average Year	400,000 ac-ft	0	33
	590,000 ac-ft	0	33
	650,000 ac-ft	0	33
Average Wet Year	400,000 ac-ft	0	33
	590,000 ac-ft	0	33
	650,000 ac-ft	0	33
Average Above Normal Year	400,000 ac-ft	0	0
	590,000 ac-ft	0	0
	650,000 ac-ft	0	0
Average Below Normal Year	400,000 ac-ft	0	33
	590,000 ac-ft	0	33
	650,000 ac-ft	0	66
Average Dry Year	400,000 ac-ft	0	66
	590,000 ac-ft	0	66
	650,000 ac-ft	50	100
Average Critically Dry Year	400,000 ac-ft	100	100
	590,000 ac-ft	100	100
	650,000 ac-ft	100	100

The East Bay Municiple Utility District studies estimated that the economic benefit of river boating is $8.2 million annually. Based on the assumption that 90 percent of all boating activities (estimated at 596,000 user days) occur between June and August, then the peak recreation season accounts for approximately $7.4 million in economic benefits annually. Each month during which recreational boating is not feasible would result in a loss of approximately $2.5 million. Based on 82 years of record (1906-1987), there is a 42 percent chance any given year will be a wet year, 12 percent an above average year, 16 percent a below average year, 18 percent a dry year, and 12 percent a critically dry year. These percentages are used to determine the average recreation losses to be expected in any given year by multiplying the monthly loss for each type of water year by the percent chance of occurrence of that category and summing the results. Table H-21 summarizes the estimated lost recreational boating values that would occur to the community as a result of implementing a flood control plan involving permanent reoperation of Folsom Dam and Reservoir.

TABLE H-21

ANNUAL COSTS - RECREATION BOATING IMPACTS
LOWER AMERICAN RIVER
($100,000)

Water Year	% Occurrence	590,000 ac-ft	650,000 ac-ft
Wet Year	42	0	0
Above Normal	12	0	0
Below Normal	16	0	384
Dry Year	18	0	432
Critically Dry	12	0	0
TOTAL	100	0	816

Part of this general recreation value includes County of Sacramento revenues from entrance fees of $3.00 per vehicle. This analysis assumes that all boating activity during this period would obtain access to the river through a controlled entrance and therefore, would pay the required fee. Assuming an average of 3.4 people per vehicle, revenues would be as much as $526,000 annually for the main recreation season (590,000 visitations/3.4 visitors per car * $3.00 per car). The only changes from the without project condition occur for the 650,000 ac-ft storage alternative during a normal (June) or dry year (July). Average annual visitation losses due to reoperation of Folsom dam and Reservoir for the 650,000 ac-ft alternative would be 64,500 (569,000/3) * (0+0+0.16+0.18+0)). Average annual revenue losses for the County of Sacramento from reoperation would amount to $56,900 for the 650,000 ac-ft alternative.

c. <u>Swimming and Wading Impacts</u>. - Swimming and wading account for 10 percent of the 5.5 million annual parkway visitations, or 550,000 annual users. While 30 percent of the total parkway use occurs during the June to September season, this analysis assumes that the percent of the total swimming and wading activity that occurs during this period is 80 percent or 440,000 visits. Assuming 25 percent of those visits occur each month, each month of the peak swimming and wading season account for 110,000 visits. Monthly average flows below the identified minimum are assumed to result in a total loss of that activity during the month when the below minimum flows occur.

Table H-19 shows that average monthly lower American River flows fall below the 1,500 cfs threshold for swimming and wading only during dry and critically dry water years. During the peak recreation season of June to September, this occurs only during the months of June and September for the 650,000 ac-ft storage alternative in a dry year. During a critically dry year threshold flows for these activities are not met for the base condition or the two reoperation alternatives. Therefore, the only impact to swimming and wading from reoperation would occur during June and September of a dry year. Table H-20 also summarizes this information.

With an average user day valued at $5.70, peak season swimming and wading values amount to $2.5 million annually. Each month during which recreational boating is not feasible would result in a loss of approximate $625,000. Using the percent chance of occurrence of a particular type of water year, average recreation losses to be expected in any given year are determined by multiplying the monthly loss for each type of water year by the percent chance of occurrence of that category and summing the results. Table H-22 summarizes the estimated lost recreational swimming and wading values that would occur to the community as a result of implementing a flood control plan involving permanent reoperation of Folsom Dam and Reservoir.

Again, part of this general recreation value includes County of Sacramento revenue from entrance fees of $3.00 per vehicle. This analysis assumes that all swimming and wading activity during this period would obtain access to the river through a controlled entrance and therefore would pay the required fee. Assuming an average of 3.4 people per vehicle, revenues would be as much as $485,000 annually for the main recreation season (550,000 visitations/3.4 visitors per car * $3,00 per car). The only changes from the without project condition occur for the 650,000 ac-ft storage alternative during a dry year (June and September). Average annual visitation losses due to reoperation of Folsom Dam and Reservoir for the 650,000 ac-ft alternative would be 49,500 ((550,000/4) * 2 * (0+0+0+0.18+0). Average annual revenue losses for the County of Sacramento from reoperation would amount to $43,700 for the 650,000 ac-ft alternative.

TABLE H-20
ANNUAL COSTS - RECREATION SWIMMING AND WADING IMPACTS
LOWER AMERICAN RIVER
($10,000)

Water Year	% Occurrence	590,000 ac-ft	650,000 ac-ft
Wet Year	42	0	0
Above Normal	12	0	0
Below Normal	16	0	0
Dry Year	18	0	225
Critically Dry	12	0	0
TOTAL	100	0	225

In other months, particularly fall and winter of dry and critically dry years, differences in the downstream flow volumes do occur. However, these months are outside of the peak recreation period and therefore are assumed to have little impact on total recreation use.

American River Watershed Investigation, California

APPENDIX I

Pertinent Data on Folsom Dam and Auburn Project

AMERICAN RIVER WATERSHED INVESTIGATION, CALIFORNIA
FEASIBILITY REPORT

APPENDIX I

PERTINENT DATA ON FOLSOM DAM AND AUBURN PROJECT

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PERTINENT DATA ON FOLSOM DAM AND AUBURN PROJECT APPENDIX

CHAPTER I - FOLSOM DAM AND RESERVOIR

1. History. - Folsom Dam is a multipurpose project constructed by the Sacramento District, Corps of Engineers and operated by the U.S. Bureau of Reclamation (USBR) as part of the Central Valley Project (CVP). Folsom Dam regulates runoff from about 1,860 square miles of drainage area. Folsom Lake has a normal full pool storage capacity of 1,010,000 acre-feet with a seasonally designated flood control storage space of 400,000 acre-feet. Reservoir releases are controlled by two tiers of flood control outlets located in the main dam. Each tier has four outlets 5 feet wide by 50 feet high, and five radial-type spillway gates 42 feet wide by 50 feet high and three radial-type emergency spillway gates 42 feet wide by 53 feet high. The Corps Water Control Manual for Folsom Dam and Lake lists physical and operational features of the project. Plates I-1 to I-3 contain pertinent excerpts from that manual and related documents. Plates L-13 and L-14 in Reservoir Regulation Appendix (Appendix L) also contain relevant information.

Nimbus Dam and its reservoir, known as Lake Natoma, are located about 6 miles downstream from Folsom Dam. Nimbus Dam, a power afterbay to Folsom Dam, is a diversion dam constructed and operated by the USBR also as part of the CVP. The reservoir has a capacity of 8,760 acre-feet. Because of the small capacity, it essentially has no regulatory effect on floodflows in the American River.

The degree of flood protection along the lower American River is estimated based on the expected frequency of flows exceeding the Reservoir Design Flood (400,000 acre-feet of flood control storage with a maximum outflow of 115,000 cfs). The Reservoir Design Flood for Folsom, developed in 1945, is an estimate of the flood that would have resulted from the most critical storm that had been recorded in the climatic region. A study of the precipitation during storms of record in the region up to that time indicated that the December 1937 storm was the most critical. The Reservoir Designed Peak has a peak flow of 340,000 cfs and a volume of 978,000 acre-feet of runoff in 6 days.

When Folsom Dam was constructed, protection against the Reservoir Design Flood was considered to be very high. However, primarily because of additional years of flow record, the Reservoir Design is now estimated to occur much more frequently. Since the completion of Folsom Dam in 1956, three rain floods exceeded the volume of the Reservoir Design Flood (December 1955, December 1964, and February 1986).

2. Description of Project.

a. Location. - Folsom Dam and Lake is located on the American River about 26 miles upstream from its confluence with the Sacramento River. The dam is in Sacramento County while the lake spans three counties including Sacramento, Placer, and El Dorado Counties. It is 20 miles northeast of the City of Sacramento and 2 miles north of Folsom Dam. Access to the various features of the project is provided by a network of county roads which connect with the U.S. Highway 50 near the City of Folsom.

b. Purpose. - The Folsom Project is operated as an integral part of the Bureau of Reclamation Central Valley Project. The reservoir provides flood control, water supply for irrigation and municipal uses, and hydropower. In addition, it provides extensive water-related recreational opportunities. Releases from Folsom are also used to provide water quality control for project diversions from the Sacramento-San Joaquin Delta and to maintain anadromous fish runs in the American River below the dam.

c. Physical Components. - Table I-1 is a listing of the main physical characteristics of Folsom Dam and Reservoir.

(1) Dam. - The Folsom Dam consists of a concrete gravity section across the river channel, with a maximum height of 340 feet from the lowest point of the foundation to the crown of the roadway, flanked by long earthen wing dams extending from the concrete section to high ground on either side of the river. The main dam, topped with a 30 foot roadway, has a crest elevation of 480.5 feet MSL and a length including spillway and flanking non-overflow sections of 1,400 feet. Plans, profiles and sections of the dam and appurtenances are shown on Plates I-1 and I-2.

(2) Wing Dams. - The wing dams are zoned embankment dams that extend from the Concrete Gravity Dam to high ground on either side of the river. The Right Wing Dam has a crest length of 6,765 feet and a maximum height of about 195 feet. The dam core consists of well-compacted decomposed granite and suitable fine-grained materials from the American River channel. Gravels excavated from the American River channel are used as upstream and downstream transition zones. An uncompacted rock-fill shell was constructed on the upstream and downstream slopes over most of the length of the dam. The Left Wing Dam has a crest length of 2,065 feet and is 167 feet high. The upstream and downstream shells are constructed of gravels which came from dredged

tailings in the Blue Ravine. The filters are the minus 2-inch fraction of the Blue Ravine gravels.

(3) Mormon Island Auxiliary Dam. - Mormon Island Auxiliary Dam is about 2.5 miles east of the Concrete Gravity Dam, and was constructed across Blue Ravine, an ancient channel of the American River. Mormon Island Auxiliary Dam is a zoned embankment dam 4,820 feet long, 165 feet high from core trench to crest at maximum section, and 30 feet wide at the crest. The shells are constructed of compacted gravel from the dredged tailings from the Blue Ravine. The narrow, central impervious core is a well-compacted clayey mixture founded directly on rock over the entire length of the dam. Two transition zones, each 12-feet wide, flank both the upstream and downstream sides of the core.

(4) Dikes. - Eight saddle dikes, having a total crest length of about 11,300 feet, span topographic saddles that surround the Folsom Reservoir. The eight dikes have essentially homogeneous sections consisting of well-compacted decomposed granite. Protective rock blankets are placed on the upstream and downstream slopes of the dikes. The dikes range in length from 740 to 2,060 feet, in height from 10 to 100 feet, and in crest width from 20 to 25 feet.

(5) Outlet. - There are four 5 by 9 foot gated outlets through the main spillway section of the dam with an invert elevation of 205.5 feet MSL and a similar group of four with an inverted elevation of 275.5 feet MSL. There are also three 15.5 foot diameter power penstocks to the Folsom Powerplant through the main dam on the right of the spillway with an intake centerline elevation of 307 feet MSL. A 7-foot diameter conduit at elevation 317 feet MSL and a pumphouse have been provided for furnishing water to San Juan Suburban Water District, City of Roseville, City of Folsom, and Folsom Prison to replace the Natoma and North Fork ditches which were inundated by the reservoir.

(6) Spillway. - The main spillway is located in the center of the concrete dam with an ogee crest having a total net length of 210 feet and is controlled by five 42 by 50-foot radial gates. The flow over this section of the spillway is discharged into a stilling basin 242 feet wide. To the left of the main spillway is an auxiliary spillway with a net length of 126 feet, controlled by three 42 by 53-foot radial gates. This portion of the spillway has a flip-bucket energy dissipater, intended for use only during extreme flood periods. The release relationships for the facility are shown in the Reservoir Regulation Appendix (Appendix L), Plate 14.

(7) Reservoir. - The lower portion of the reservoir ranges from 3 to 4 miles in width, while the upper portion

consists of two main arms that branch and extend up the North and South Forks of the American River. The reservoir extends from the intersection of the original streambeds about 15 miles up the North Fork, and up the South Fork about 11 miles. Total reservoir area is about 11,450 acres at gross pool, and 2,030 acres at the inactive pool. The lake is a popular site for a variety of recreational activities, attracting over 20,000 people on busier days. Recreational activities include boating, water skiing, swimming, fishing, hiking, camping, picnicking, horseback riding, and nature study. An area capacity curve for Folsom Reservoir is shown on Plate I-3.

(8) Nimbus Dam. - Nimbus Dam is an afterbay structure, constructed and operated by the USBR to reregulate the flows of the American River through the Folsom Powerplant, to act as a diversion dam to direct water into the proposed Folsom South Canal and to create a forebay for the Nimbus generators.

d. Public Facilities. - The California Department of Parks and Recreation has a management agreement with the USBR to develop, operate, and maintain the Federal land around Folsom Lake and Lake Natoma. The Folsom Lake State Recreation Area, as stated by the Department of Parks and Recreation, is to make available the great recreational opportunities afforded by the reservoirs impounded at Nimbus and Folsom Dams on the American River, including aquatic features, environmental amenities, and historic value of locality. Recreation activities include boating, water skiing, swimming, fishing, hiking, camping, picnicking, horseback riding and nature study.

3. Reservoir Operation Criteria. - Documentation of operation procedures is contained in the "Folsom Dam and Lake, American River, California, Water Control Manual," December 1987.

a. Objectives. - Folsom Dam and Reservoir is operated to meet the following objectives:

- To help protect the City of Sacramento and other areas within the lower American River flood plain against reasonably probable rain floods.

- To control flows in the American River downstream from Folsom Dam to 115,000 cfs, insofar as practicable, and to reduce flooding along the lower Sacramento River and in the Sacramento-San Joaquin Delta in conjunction with other Central Valley projects.

- To provide the maximum amount of water conservation storage without impairment of the flood control functions of the reservoir.

- To provide the maximum amount of power practicable and be consistent with required flood control operations and the conservation functions of the reservoir.

- To provide releases to enhance an anadromous fishery on the lower American River.

- To provide acceptable water quality for users in the American River and to meet water quality standards in the Sacramento-San Joaquin Delta.

b. Reservoir Operation for Flood Control. - The USBR operates Folsom Dam and Reservoir for flood control in accordance with the flood control diagram developed by the Corps of Engineers (see Plate L-13, Reservoir Regulation Appendix). Flood control regulation begins when storage in Folsom Reservoir reduces the flood control space available to less than required at any particular time as determined from the flood control diagram. Flood Control space requirements increase from zero on October 1 to a maximum of 400,000 acre-feet from November 17 through February 8. A joint-use space requirement is available from February 8 to May 31. This space varies according to parameters based on the accumulation of seasonal precipitation. The variable space includes the required flood space while allowing the remaining space to be filled for conservation purposes.

Water is released as rapidly as allowed when the pool is in the flood space to ensure sufficient space for future inflow. Maximum flood releases are restricted to the lesser of the maximum inflow to the reservoir or 115,000 cfs. Releases must exceed 20,000 cfs if the rate of inflow is above 20,000 cfs and is increasing. Releases are not increased more than 15,000 cfs during any 2-hour period to allow any persons in the river channel area an opportunity to leave as the water surface rises. Releases also are not decreased more than 10,000 cfs during any 2-hour period to minimize sloughing of the downstream levees.

c. Emergency Operation of the Gated Spillway. - A severe flood can be defined by various combinations of existing reservoir pool elevation, the rate of rise of the reservoir, and the forecast of future inflows. During a severe flood, where the pool exceeds elevation 448 feet above MSL and is rising, flood control release will be required. These releases are made in accordance with the Emergency Spillway Release Diagram (ESRD). The ESRD gives the minimum permissible release that can be made without endangering the structure and without releasing quantities in excess of natural runoff. Releases greater than those given by the ESRD may be made to ensure the integrity of Folsom Dam. If the ESRD indicates a release of less than 115,000 cfs, then the Flood Control Diagram is used.

The ESRD is based on the minimum volume of remaining inflow when only reservoir elevations and inflow are known. This minimum volume of remaining inflow is estimated on the basis that the inflow peak has past and that recession of flow is expected to be somewhat steeper than in most observed floods. The diagram is thus designed to defer emergency releases until it is virtually certain that those emergency releases or larger releases will be necessary. Use of the ESRD is explained in the Water Control Manual.

d. Probable Maximum Flood. - The Probable Maximum Flood (PMF) is considered to be the most severe flood that has a reasonable chance to occur. It results from the most extreme combination of critical meteorological and hydrologic conditions that are reasonably possible for a region. Estimates of the return frequency of a PMF range from 1 in 100,000 years (1:100,000) to 1 in 1,000,000 years (1:1,000,000). The largest historical floods in the Sierra Nevada result from large rainstorms dumping warm precipitation onto a snow-covered basin. The original design of the Folsom Dam spillway was calculated using a Probable Maximum Precipitation (PMP) event developed by the Weather Bureau (now the National Weather Service).

Hydrometeorological Report Number 36, published in 1961 and revised in 1969, updated the PMP criteria for California. The updated PMP storm (updated from the original 1946 estimate) was developed for the American River basin upstream of Folsom Dam and a rain-on-snow analysis was made. The PMP totaled 32.83 inches over 72 hours, of which 7.12 inches was lost due to infiltration. The snowmelt contributed another 2.1 inches of water to the runoff volume. An updated PMF (with upstream dam failures) has a peak flow of 1,037,000 cfs and a total volume of 2,657,000 acre-feet. Also an updated PMF (without the upstream dam failures) has a peak flow of 848,000 cfs and a total volume of 2,495,000 acre-feet.

An office report on spillway adequacy, completed in 1980 and revised in 1983 with minor changes, routed these two PMFs through Folsom Dam. These PMF routings utilized the ESRD published in the Water Control Manual. The routings used a starting elevation in the reservoir at gross pool (elevation 466.0 feet above MSL), the normal maximum operating level, with the reservoir releasing 115,000 cfs. Releases were assumed to come through the spillway only.

When the PMF with upstream dam failures is routed through the reservoir, the reservoir stage exceeds the lowest point located on the dam and its embankment structures by 2.7 feet, assuming that no dam embankments fail. Routing the PMF without the upstream dam failures through Folsom Dam produced a stage 1.6 feet higher than the lowest point on the dam and its embankment structures, again assuming no embankments fail. The spillway for Folsom Dam, which could accommodate the original PMF, is not able to accommodate either of the revised PMFs, resulting in a hydrological deficiency. Also, it is unlikely that any embankment structure could withstand the severity of overtopping indicated by either PMF routing.

CHAPTER II - AUBURN DAM AND RESERVOIR PROJECT

4. Background. - The CVP extends from the Cascade Range in the north to the semi-arid but fertile plains of the San Joaquin Valley in the south (see Plate I-4). The initial features of the project were authorized by President Roosevelt in 1935 for construction by the USBR; subsequently, additional features, including the Auburn-Folsom South Unit, have been authorized by the Congress.

The CVP stores and develops the surplus water supplies of the Sacramento, American, and Trinity River Basins in the northern portion of the vast Central Valley Basin, and transports them South to the water-deficient lands of the San Joaquin Valley. The project was initially developed for mitigation, but it also provides flood control, improves Sacramento River navigation, supplies domestic and industrial water, generates hydroelectric power, conserves fish and wildlife resources, provides recreational opportunities, repels saline ocean waters from the Sacramento-San Joaquin River Delta, and provides water quality enhancement. The CVP provides full supplemental and temporary water supplies to about 3 million irrigable acres, provides over 154,000 acre-feet of water annually for municipal and industrial use, and generates over 3.5 billion kilowatthours of pollution-free energy annually.

The Auburn-Folsom South Unit (Figure I-1) was authorized in September 1965 by Public Law 89-161 as an operationally and financially integrated part of the CVP. The unit includes Auburn Dam, Reservoir, and Powerplant on the North Fork American River above Folsom Lake; Folsom South Canal which will convey water from existing Nimbus Dam on the American River approximately 62 miles southward to serve a gross area of 500,000 acres and portions of Sacramento and San Joaquin Counties; Sugar Pine Dam and Reservoir and conveyance to serve the Foresthill Divide area; and County Line Dam and Reservoir and conveyance to serve the Malby area southeast of Folsom.

The Auburn-Folsom South Unit would provide power, increased flood protection for the Sacramento metropolitan area, recreation and fish enhancement, and a water supply for the CVP, including the Folsom South Canal service area. The concept of the unit at the time of authorization was to use the water supplies available from existing Folsom Lake, together with those from the planned Auburn Reservoir, to provide water to the Folsom South Canal service area. The plan consisted of a gravity diversion to the Folsom South Canal at Nimbus Dam. It was to be made after meeting all existing rights and contracts, including the maintenance of the minimum flows in the lower American River below the diversion point specified in the 1957 agreement between the USBR and the California Department of Fish and Game. However, the level of riverflows specified in the 1957 agreement (Decision-693 of the California Water Resources Control Board (250-500)) is insufficient to maintain the valuable fishery and recreation resources provided by the river. By terms of the contract between the California Department of Parks and Recreation and the Department of Water Resources, the Auburn recreation development will operate as an extension of its present activities at Folsom. Auburn Reservoir would have provided the diversion pool for future deliveries of water to western Placer County by the Placer County Water Agency through facilities already constructed by the agency. Facilities have been constructed in the Auburn Dam foundation to facilitate future service to the Georgetown Divide Public Utility District in El Dorado County.

5. <u>Construction of Auburn Dam Project</u>. - Construction of Auburn Dam was initiated in 1967 and Folsom South Canal the following year. (Plate I-5 shows the main features of the dam.) The first two reaches of the canal, or about 27 miles, have been completed. Impacts resulting from the diversions to the service area to the river increased opposition to the project. The Secretary of the Interior stopped construction, pending the outcome of studies to develop a plan which would meet the needs of both the canal service area and the river.

In 1972, the California Senate through Decision 1400 established the minimum flow for the American River under post-Auburn conditions. The State required that almost four times as much water be released past the canal diversion point as had been previously planned. The D-1400 level of lows (1,250 to 1,500 cfs) has generally been accepted as the minimum standard to maintain the river's fishery and recreation values, although these flows are not required to be met at present.

When the Oroville earthquake of August 1975 occurred, the foundation for Auburn Dam was being constructed. The earthquake led to inquiries by the public about the safety of the design for the double-curvature concrete-arch dam then planned for Auburn Dam if a major seismic event were to occur. As a result, the foundation construction contract was completed, but no further construction was undertaken. A major study was made of the seismic potential of the damsite and surrounding region, and alternative dam designs for Auburn Dam were studies. These studies, which involved the USBR, the State of California, and numerous eminent experts in the fields of geology, seismology and dam design, culminated in the Secretary of the Interior's decision of December 30, 1980. In that decision he stated that a safe dam could be constructed at the Auburn site and that the best design would be the curved-concrete gravity-type dam referred to as CG-3.

Table I-2 outlines the chronology of several important events and studies for the Auburn project.

6. <u>Costs To Date</u>. - On the basis of information provided by USBR, through September 1987, about $233 million had been spent on the Auburn area facilities. Table I-3 is a summary outline of those facilities. Table I-4 shows a breakdown of costs for the main dam and related features. Table I-5 shows a cost breakdown for the remaining features of the project. Included in Table I-6 is the Auburn area costs updated to 1990 price levels. As can be seen, approximately $237 million in construction expenditures and about $109 million in accrued interest have been applied to the authorized Auburn Dam project as of October 1990. An analysis was made of how much, if any, of those funds should be applied to construction of a new flood control project at the site. For this investigation, those previously constructed features, or portions thereof, that would need to be included in a flood control project if it were started from scratch were included in the project cost. All other liabilities are considered as sunk. It was also assumed that the interest to date would approximate price increases to current levels and (consistent with other cost items) no further interest would begin to accrue until initiation of construction. Table I-6 also summarizes the allocation of accrued interest and an estimate of whether or not the project feature would be required for a flood-control-only project. As noted in the table, project lands are treated separately.

Those costs shown in Table I-6 applicable to a flood control project ($75 million) were included as a project financial cost for Federal/non-Federal cost-sharing purposes (October 1990 price levels). These costs were credited to the Federal Government's share of the flood-control-only project cost but not included as an economic cost in the economic analysis.

TABLE I-1

FOLSOM DAM AND LAKE
AMERICAN RIVER, SACRAMENTO COUNTY, CALIFORNIA
PERTINENT DATA

General

Drainage area	
American River at Folsom Dam	1,861 sq. mi.
S Fk American River at Lotus	673 sq. mi.
N Fk American River near Auburn	614 sq. mi.
M Fk American River at N Fk Dam	342 sq. mi.
American River at Fair Oaks	1,888 sq. mi.
American River at Mouth	2,100 sq. mi.
Flows at Folsom Dam	
Mean annual unreg. runoff (1905-86)	2,788,000 ac-ft
Maximum mean daily inflow (23 Dec 55)	189,000 cfs
Max. instantaneous inflow (18 Feb 86)	900,000 cfs
Standard project flood peak inflow	530,000 cfs
Standard project flood peak outflow	530,000 cfs
Spillway design flood peak inflow	615,000 cfs
Spillway design flood peak outflow	585,000 cfs

Main Dam (concrete gravity)

Location, river mile	30
Elevation, top of parapet	484.0 feet
Streambed elevation	200.0 feet
Freeboard above spillway flood pool	7.8 feet
Elevation, crown of roadway	480.5 feet
Max. ht., foundation to roadway crown	340.0 feet
Length of crest (spillway and abutment)	1,400 feet
Width of crest at roadway	36.25feet
Width of roadway, curb to curb	30.0 feet
Excavation	960,000 cu-yd
Mass concrete	1,170,000 cu-yd

Wing Dams (rolled earth)

Crest elevation	484.0 feet
Freeboard above spillway design pool	7.8 feet
Crest width	30 feet
Roadway width, left wing dam	24 feet
Right wing dam	16 feet
Maximum height, left wing dam	145 feet
Right wing dam	145 feet
Length of crest, left wing dam	2,100 feet
Right wing dam	6,700 feet
Side slopes,	
Upstream above elev. 450	1 on 2.25
Elev. 450 to 427	1 on 3.25
Below elev. 427	1 on 3.75
Downstream	1 on 2
Total excavation	240,000 cu-yd
Total volume of embankment	7,810,000 cu-yd

Dikes (rolled earth)

Freeboard above spillway pool	4.3 feet
Width of crest-Dikes 2,3,5,7,8	20 feet
Dikes 1,4,6	25 feet
Length of crests	
Dike 1	2,060 feet
Dike 2	1,800 feet
Dike 3	1,395 feet
Dike 4	1,420 feet
Dike 5	1,940 feet
Dike 6	1,410 feet
Dike 7	890 feet
Dike 8	740 feet
Maximum heights	
Dike 1	25 feet
Dike 2	15 feet
Dike 3	10 feet
Dike 4	30 feet
Dike 5	100 feet
Dike 6	40 feet
Dike 7	35 feet
Dike 8	15 feet
Side slopes	
Upstream, crest to elev. 466	1 on 2.25
Below elev. 466	1 on 3.25
Downstream	1 on 2.25
Total excavation	140,000 cu-yd
Total volume of embankment	1,200,000 cu-yd

Lake

Elevation	
Minimum power pool (top of inactive pool)	327.0 feet
Flood control pool	427.0 feet
Gross pool (top of joint use pool)	466.0 feet
Spillway design flood pool	476.2 feet
Top of induced surcharge pool	475.4 feet
Guide taking line	466.0 feet elev +300 ft landward
Area	
Minimum power pool	2,030 acres
Flood control pool	9,040 acres
Gross pool	11,450 acres
Spillway flood pool	11,960 acres
Guide taking line	12,000 acres
Acquisition line	15,754 acres
Storage capacity	
Minimum power pool	90,000 ac-ft
Flood control pool	610,000 ac-ft
Gross pool	1,010,000 ac-ft
Spillway flood pool	1,130,000 ac-ft

Spillway (gated ogee)

Crest length	
Gross	392 feet
Net	336 feet
Crest elevation	418.0 feet
Design head	50 feet
Spillway flood head	58.2 feet
Capacity	567,000 cfs
Crest gates (tainter), number and size	3-42x53 feet 5-42x50 feet
Seat elevation	417.16
Top elevation when closed	3-471.0 feet 5-468.0 feet

Outlets

River outlets (2 tiers), each tier:	
Outlets, number and size	4-5x9 feet
Service gates (hydraulic slide)	4-5x9 feet
Emergency gates (hydraulic slide)	4-5x9 feet
Intake elev., invert, lower tier	205.5 feet
Upper tier	275.5 feet
Length of conduit, lower tier	229.31 feet
Upper tier	169.04 feet
Fixed-wheel gate (for all conduits)	1-8.33x15.07 ft
Pumping outlet	
Number and size	1-84" diameter
Intake elevation, centerline	317 feet
Gate valve	1-60"
Total capacity	
With water surface elev. 290.0	13,100 cfs
With water surface elev. 427.0	28,600 cfs

Power Penstock (steel-lined)

Number and size	3-15.5 ft dia.
Intake elevation, centerline	307 feet
Fixed wheel gates	3-12.78x24.52 ft
Generator capacity, 3 units	198,720 kW

Mormon Island Dam (rolled earth)

Crest elevation	480.5 feet
Freeboard above spillway flood pool	4.3 feet
Crest width	30 feet
Maximum height	110 feet
Crest length	4,820 feet
Side slopes	
Upstream, crest to elev. 466	1 on 2
Elev. 466 to elev. 427	1 on 3
Below elev. 427	1 on 4.5
Downstream, crest to elev. 466	1 on 2
Elev. 466 to elev. 427	1 on 2.5
Below elev. 427	1 on 3.5
Undredged valley and abument section	
Upstream and downstream slope	1 on 2
Total excavation	1,082,000 cu-yd
Total volume of embankment	3,820,000 cu-yd

TABLE I-2[1]

Chronology of Studies and Events, 1958-1987
Auburn-Folsom South Unit

1958 State Water Resources Control Board Decision 893 (D-893) establishes minimum flows of 250-500 cubic feet per second (cfs) (234,000 acre-feet per year) in the Lower American River to provide for anadromous fish populations.

1965 Auburn-Folsom South Unit of the Central Valley Project is authorized by Public Law 89-161. Authorization includes Auburn Dam, Reservoir, and Powerplant; Folsom South Canal; Sugar Pine Dam and Reservoir and M&I pipeline; County Line Dam and Reservoir and conveyance. (Folsom-Malby area facilities).

1967 Construction of Auburn Dam begins.

1968 Construction of Folsom South Canal begins.

1972 State Water Resources Control Board Decision 1400 (D-1400) establishes minimum flows of 1,250-1,500 cfs in the Lower American River, from Nimbus to the mouth, to come into effect with the completion of Auburn Dam.

Construction of 33-foot diameter, 2,400-foot-long Auburn Dam diversion tunnel is completed.

1973 Two of the five reaches of Folsom South Canal are completed. Future construction of the remaining three reaches is deferred pending studies of minimum flows and water supply commitments.

1975 Initial construction of 265-foot-high cofferdam completed and well underway for keyway excavation and foundation treatment.

Oroville Earthquake. Construction on Auburn Dam and Powerplant suspended pending further seismic evaluation.

1975-1980 Reclamation, with the State of California overview conducts seismic studies on Auburn damsite and develops alternative designs. Cofferdam raised 15 feet in 1978 to extend flood protection.

1980 Secretary of the Interior announces that Auburn Dam is seismically safe, but defers further construction until Lower American River flow issues are resolved. (Concrete gravity dam recommended as safest design.)

1982 Reclamation and U.S. Fish and Wildlife Service complete studies indicating that an optimum fishery on the Lower American River would require higher minimum flows than those provided in D-1400.

1984 The President announces a national policy calling for project beneficiaries to share in the costs of financing water projects and ultimately assume a substantial share of development costs.

Joint State-Federal Auburn Dam Task Force is established to review cost allocations, determine financial capability of beneficiaries, and recommend possible contractual mechanisms.

Reclamation and the Department of Water Resources prepare a joint report, Options For Auburn-Folsom South Unit, presenting options on constructing, operating, and financing completion of Auburn Dam. Seventeen non-Federal entities, including the State of California, express interest in cost sharing.

1985 The Department of Water Resources and Reclamation contract with Bechtel National, Inc., to evaluate a curved, concrete gravity dam design developed during the 1975-80 seismic studies and determine if there is a less costly option that could provide the same level of water supply, power generation, and flood control.

Bechtel National, Inc., completes its Final Report on the Evaluation of the Auburn Dam Project. Findings: Substantial money could be saved by constructing a straight roller-compacted concrete gravity dam at River Mile 19.0 with a 300- or 400- megawatt (MW) powerplant and reservoirs ranging in size from 800,000 to 2,326,000 acre-feet. The addition of pumped storage capability could significantly improve project economics.

1986 Technical experts from Reclamation, Department of Water Resources, Western Area Power Administration, and Congressman Shumway's office, complete analysis of the Bechtel Report. Their report Evaluation of Auburn Dam Reformulation and Bechtel Report recommends a straight-axis concrete gravity dam at the existing Mile 20.1 site because of work already completed and amount of information available.

1986 February floods result in record riverflows. Peak outflows from Folsom Reservoir of 130,000 cfs exceed the reservoir design releases of 115,000 cfs. Cofferdam at the Auburn damsite partially washes away.

Reclamation and the Department of Water Resources ask the Corps of Engineers to review and update the hydrology of the American River, determine areas of potential flooding, update alternative flood control measures, and re-evaluate flood control benefits of these measures.

1987 The March Corps' report, Special Study on the Lower American River, California, reveals that the February flood was a 70-year event; Folsom Reservoir can control only a 63-year flood to 115,000 cfs, and peak flows for a 100-year flood in the Lower American would be 230,000 cfs.

1987 H.R. Bill 1605, the Auburn Dam Revival Act of 1987, is introduced on March 12, 1987 by Congressman Shumway. The bill amends the 1965 Act and the Flood Control Act of 1970 to provide for non-Federal cost sharing in the project and to set minimim flows at 1,250-2,000 cfs in the Lower American River.

[1]Source: USBR; Auburn Dam Report, Auburn-Folsom South Unit Central Valley Project; July 1987.

TABLE I-3

SUMMARY OF COSTS - AUBURN AREA FACILITIES[1]

Item	Cost
Dam	$216,888,540
Recreation	5,668,247
Service	1,740,444
Fish and Wildlife	330,345
Permanent Operating Facilities	36,167
Powerplant	8,372,852
Total	$233,036,595

[1]Total spent through September 30, 1987

TABLE I-4

AUBURN DAM - DAM AND RELEASE COSTS[1]

Item	Cost	Item	Cost
Lands and Rights	$9,938,273	Auburn-Foresthill Road	$15,446,713
BLM Mining Claim Study	274,795	Indian Hill Road	702,950
Appraisal Contracts	98,494	Pacific Avenue	374,029
Clearing Dam & Res.	233,362	Diversion Tunnel	6,525,974
Cofferdam Modifications	38,848	Maidu Drive	39,204
Diversion Tunnel Repair	63,878	Highway 49 "D"	3,285,689
Flood Damages Cofferdam	595,000	North Fork Road Survey	224,937
Highway 49	1,991,371	Middle Fork Raod	129,530
Canyon Access Road	15,240	Security Force-Rock Quarry	42,537
Drill Core Storage	24,490	Highway 49 "D" Sacramento St. Mod.	88,910
Unidentified Damages	120,345	Exploratory Tunnels	2,003,279
Maintain Highway 49	447,741	Pioneering Construction Access	190,204
Rights-of-Way - Auburn	1,081,025	Log Boom Construction	41,104
Misc. Utilities & Trails	839,981	Revegetation	6,404
Fire Prevention, State Forestry	1,176,326	Auburn-Foresthill Bridge Superstructure Repair	4,773
Seismic Network	1,130,629	Ruck-A-Chucky Bridge Design	1,449,474
Interim Resource Management	3,235,905	Earthquake Evaluation	1,683,098
Misc. Agreements	577,054	Excav. & Foundation Treatment	94,512,811
Water Rights	172,156	Subtotal - Dam	150,259,051
Overlook Parking	187,000	Minor Contracts	2,808,490
Seismograph Station	23,855	Design Costs	14,820,301
Revegetation of Cut Slopes	20,067	Non-Contract Costs	49,000,698
Access Roads	655,953	Total - Dam	216,888,540

[1]Total spent through September 30, 1987.

TABLE I-5.

AUBURN DAM - REMAINING MAIN FEATURES COSTS[1]

Recreation

Lands & Rights	$3,988,000
General Rec. Plan	626,026
Recreation Facilities Salt Cr. Boat Ramp	567,622
Subtotal - Recreation	$5,180,648
Minor Contracts	36,294
Design Costs	434
Non-Contracts	450,871
Total - Recreation	$5,668,247

Service Facilities

Temp. Storage Bldg. & Shop Bldg.	$ 22,768
Utilities & Complete Roadway	128,405
Dam Service Facilities Complex	467,984
Revegetation of Cut & Fill	210
Dam Access Road	80,602
Service Facilities Complex Completion	73,839
Administration Bldg.	966,636
Total - Svc. Facilities	$1,740,444

Fish and Wildlife

Lands & Rights	$ 320,000
Non Contracts	10,345
Total Fish & Wildlife	330,345

Permanent Operating Facilities

Visitor Center Bldg.	$ 34,000
Non-Contracts	2,167
Total - Perm. Op. Fac.	$ 36,167

Powerplant

Access Road	$ 829,143
Revegetation	3,935
Excavation & Foundation Treat.	3,330,111
Subtotal - Powerplant	$4,163,189
Minor Contracts	39,425
Design Costs	3,340,509
Non-Contract Costs	829,729
Total - Powerplant	$8,372,852

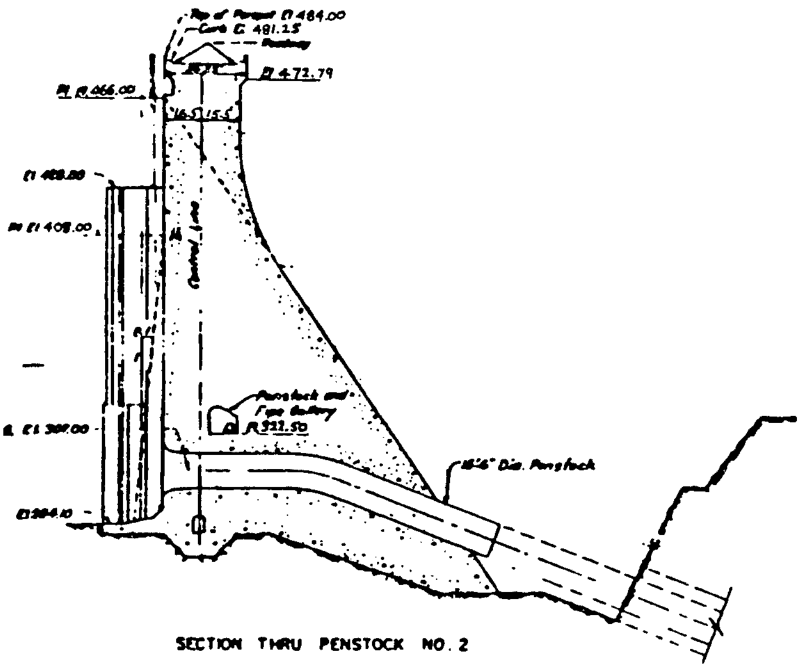
[1]Total spent through September 30, 1987.

TABLE I-6

COSTS TO DATE PROPORTIONED TO FLOOD CONTROL

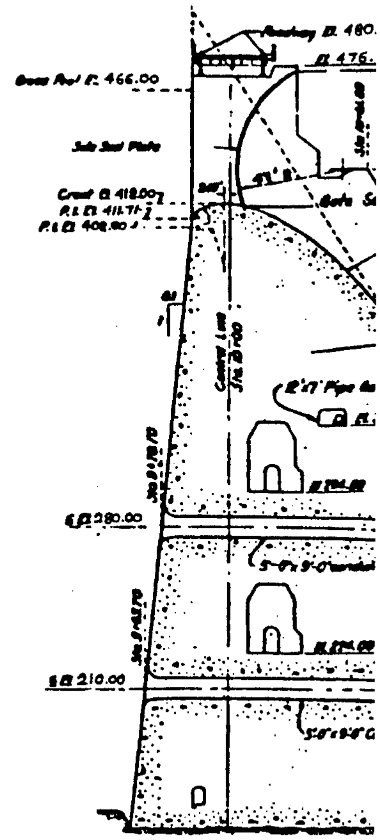
Program Activity	Total Cost Thru 9/30/90 1/	Percent Cost Applicable to Flood Control Project	Total
Lands and Rights	$ 9,938,273	3/	$ 3/
BLM Mining Claim Study	247,795	100	274,795
Appraisal Contracts	98,495	26	25,608
Clear Dam/Reservoir Area	233,362	100	233,362
Misc. Utilities and Trails	839,981	50	419,991
Seismograph Network	1,273,729	50	636,865
Fire Protection - State Forestry	472,143	100	472,143
Land Resources Management - State Parks	4,481,986	50	2,240,993
Miscellaneous Agreements	577,054	0	0
Water Rights	172,155	0	0
Miscellaneous Equipment Rental	540,079	0	0
Future Visitors Center - Overlooking Park	187,000	0	0
Seismograph Station	23,855	100	23,855
dam Access roads	676,020	80	540,816
Auburn-Forest Hill Road	15,477,051	100	15,477,051
Indian Hill Road	702,950	100	702,950
Pacific Avenue	374,029	100	374,029
Diversion Tunnel	6,525,974	100	6,525,974
Maidu Drive Extension	39,204	100	39,204
Highway 49 ROW thru the city of Auburn	1,081,025	25	270,256
Highway 49 "D" Portion	3,285,689	25	821,422
Highway 49 "D" Portion Sacramento Street Modifications	88,910	0	0
North Fork Road Survey	224,937	0	0
Middle Fork Road Survey	129,530	0	0
Security Force-Rock Quarry	42,537	0	0
Exploratory Tunnels	2,003,279	50	1,001,640
Pioneering Construction Access	190,204	100	190,204
Log Boom Construction	41,104	100	41,104
Revegetation	6,404	0	0
Design of Ruck-a-Chucky Bridge	1,449,474	0	0
Earthquake Evaluation	1,683,098	50	841,549
Excavation and Foundation Treatment	94,512,811	13	12,286,665
Minor Contracts	4,555,426	11	501,097
Non-Contract Costs	65,514,095	11	7,206,550
Auburn Dam and Reservoir	$217,716,657		$ 51,148,123
Cofferdam Modifications	38,848	0	0
Diversion Tunnel Repair	63,878	0	0
Maintain Highway 49 - State of California	537,028	0	0
Flood Damage Repairs - Contracts	2,746,446	0	0
Fire Protection - State Forestry 4/	1,101,666	0	0
Placer County Pump Rehabilitation	423,378	0	0
Placer County Pump Removal - 1989	20,001	0	0
Placer County Pump Removal - 1990	25,000	0	0
Costs resulting from Construction Delay	5,231,040	0	0
Auburn Powerplant	8,372,852	0	0
Recreation Facilities	5,668,737	0	0
Permanent Operating Facilities	36,167	0	0
Fish and Wildlife Lands	330,345	0	0
Subtotal - Construction Costs	237,355,798		$ 51,148,123
Interest During Construction	109,393,053	5/	23,573,257
Total Auburn Area Facilities	$346,748,851		$ 74,721,380

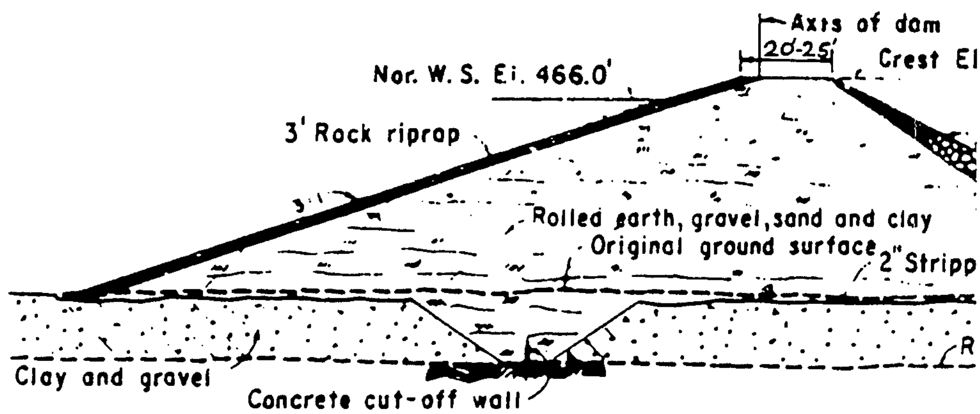
1/ Costs incurred by U. S. Bureau of Reclamation for construction of authorized Auburn Dam and related facilities. Includes interest on actual expenditures.
2/ Estimated (percent and total) cost creditable to flood detention dam.
3/ Lands to be evaluated separately by Corps of Engineers.
4/ Contract with State Forestry since fiscal year 1970, and construction delayed in fiscal year 1976, so 6/20 of 30 percent of costs assigned to cost of dam.
5/ Prorata share based on ratio of total construction costs.



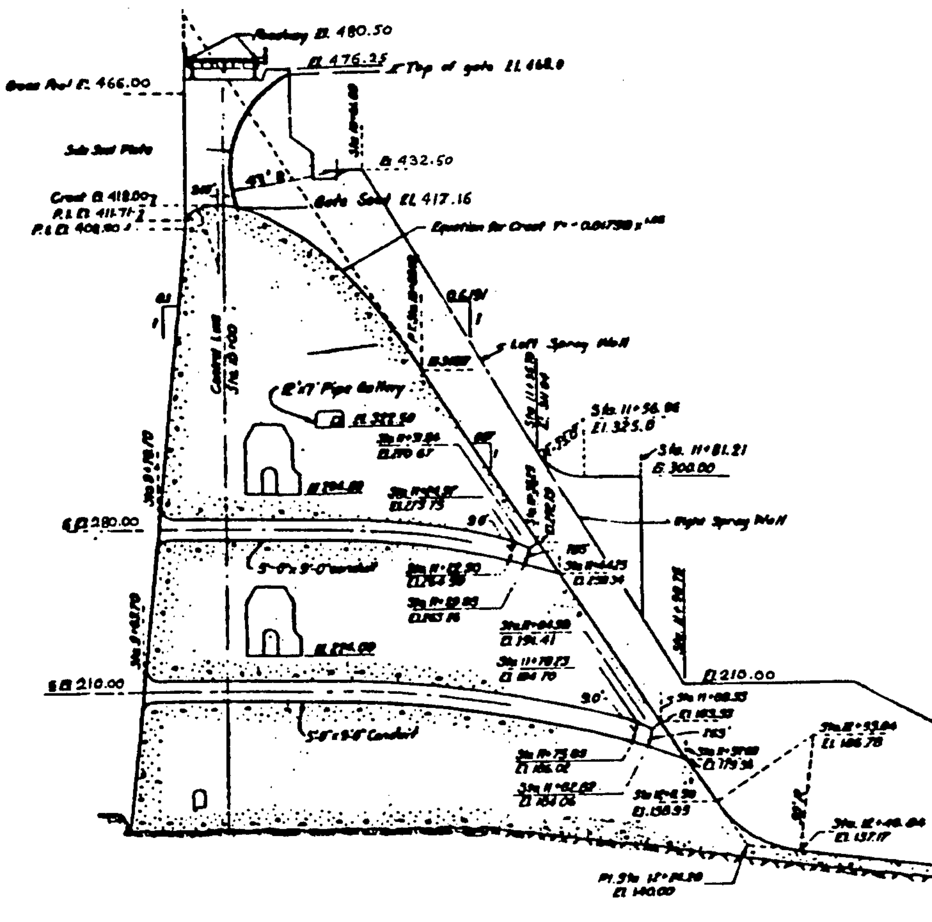
SECTION THRU PENSTOCK NO. 2

STA 289 + 80 - MONOLITH NO 3

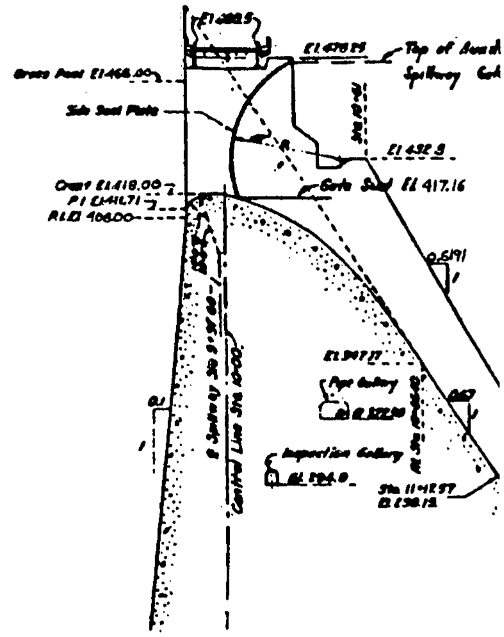




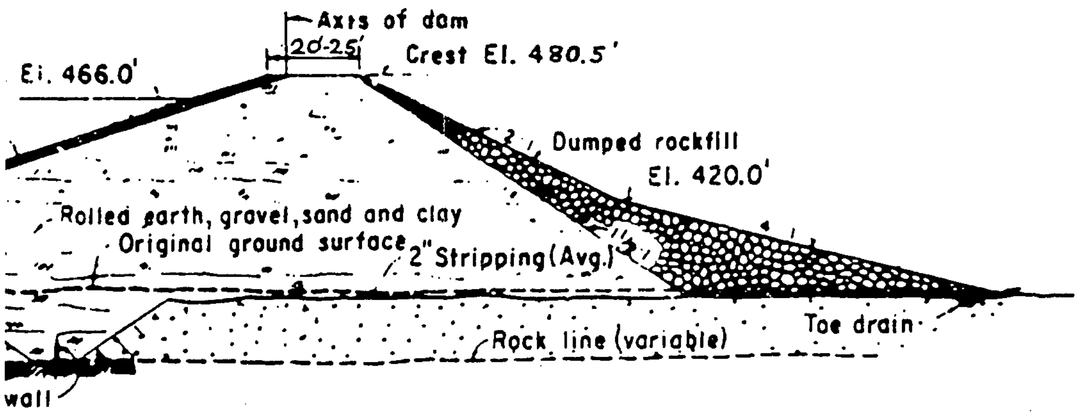
TYPICAL SECTION OF DIKE



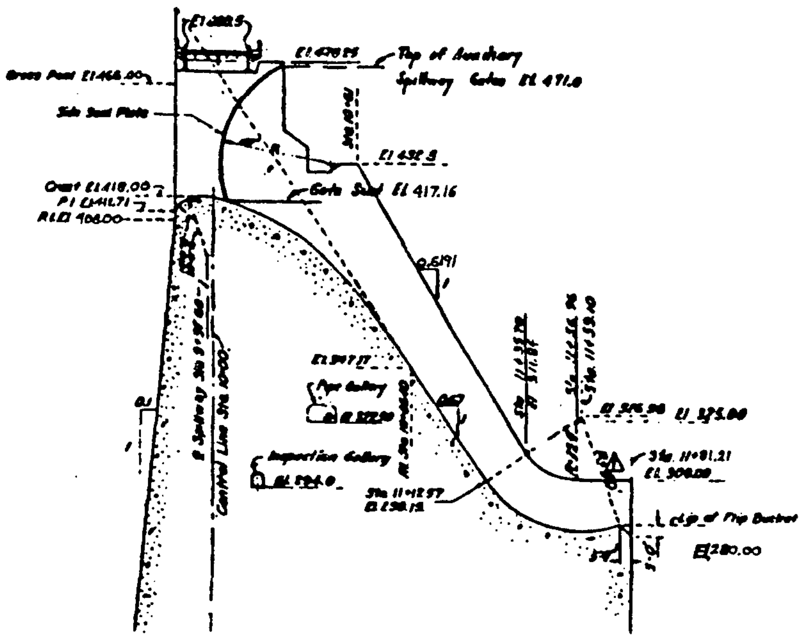
SECTION THRU STILLING BASIN



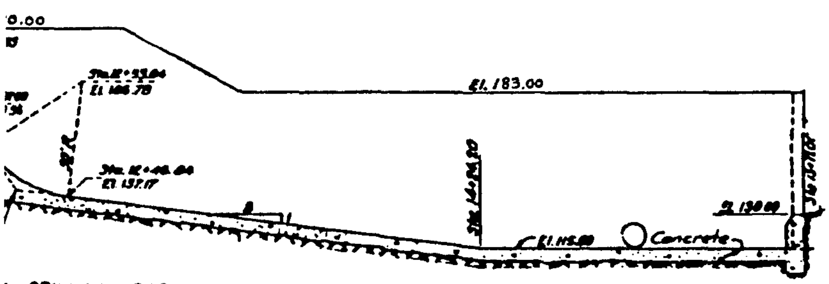
SECTION THRU FLIP BUC



TYPICAL SECTION OF DIKE



SECTION THRU FLIP BUCKET



STILLING BASIN

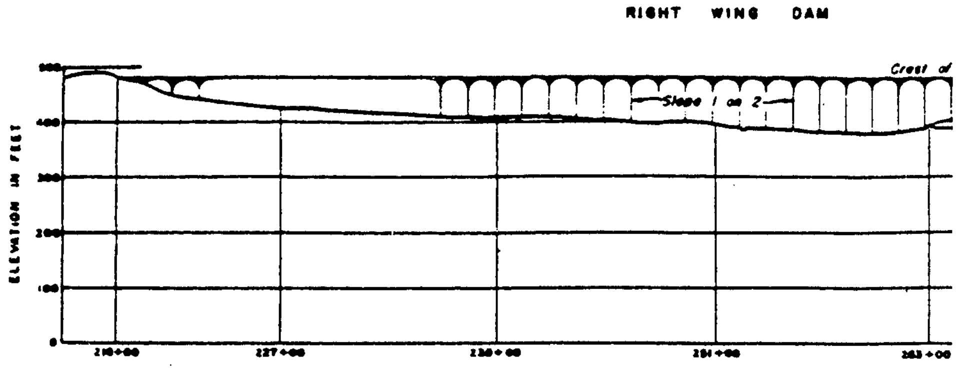
SCALE IN FEET

0 30 60 90 120

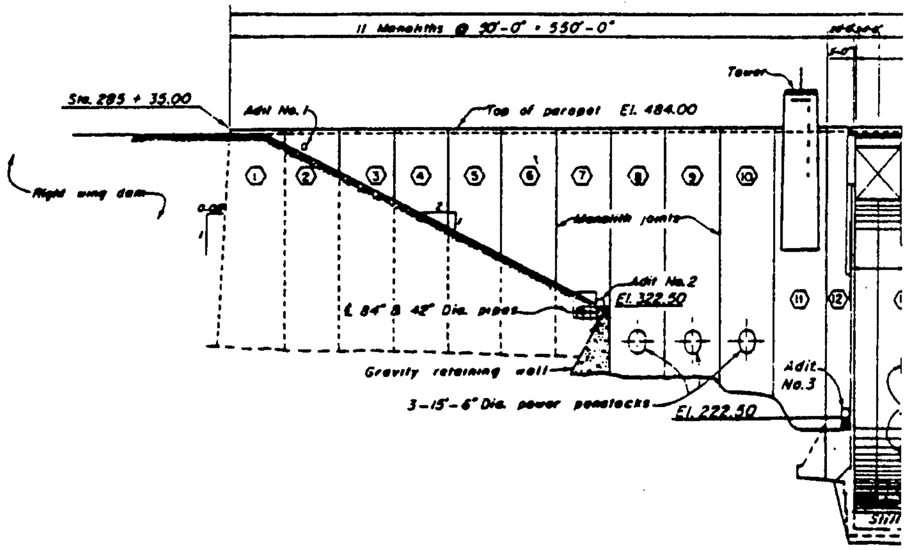
FOLSOM DAM AND LAKE
AMERICAN RIVER, CALIFORNIA

FOLSOM DAM
AND DIKE SECTIONS

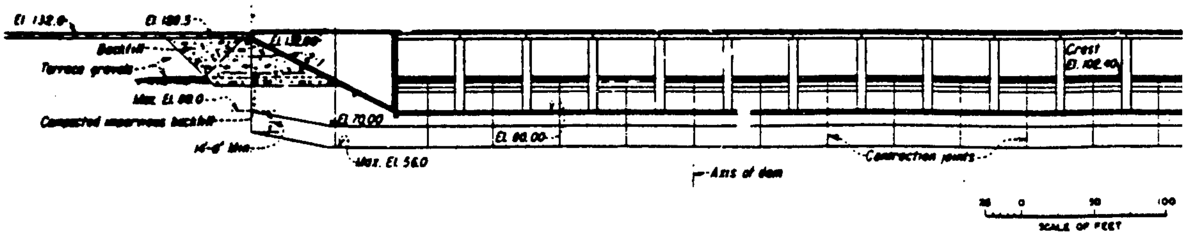
U.S. ARMY CORPS OF ENGINEERS
SACRAMENTO DISTRICT



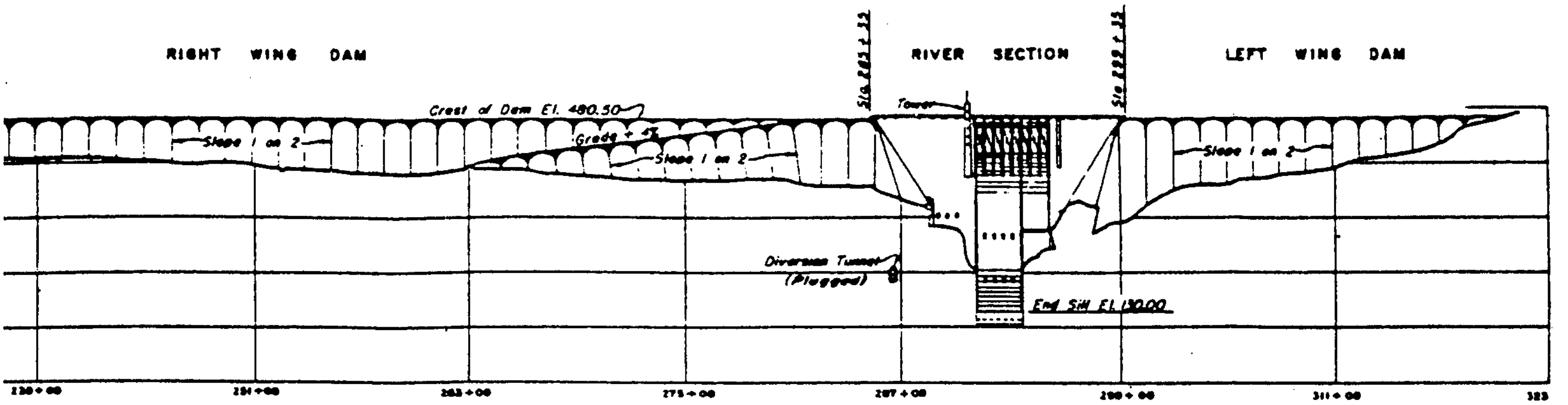
MAIN FOLSOM



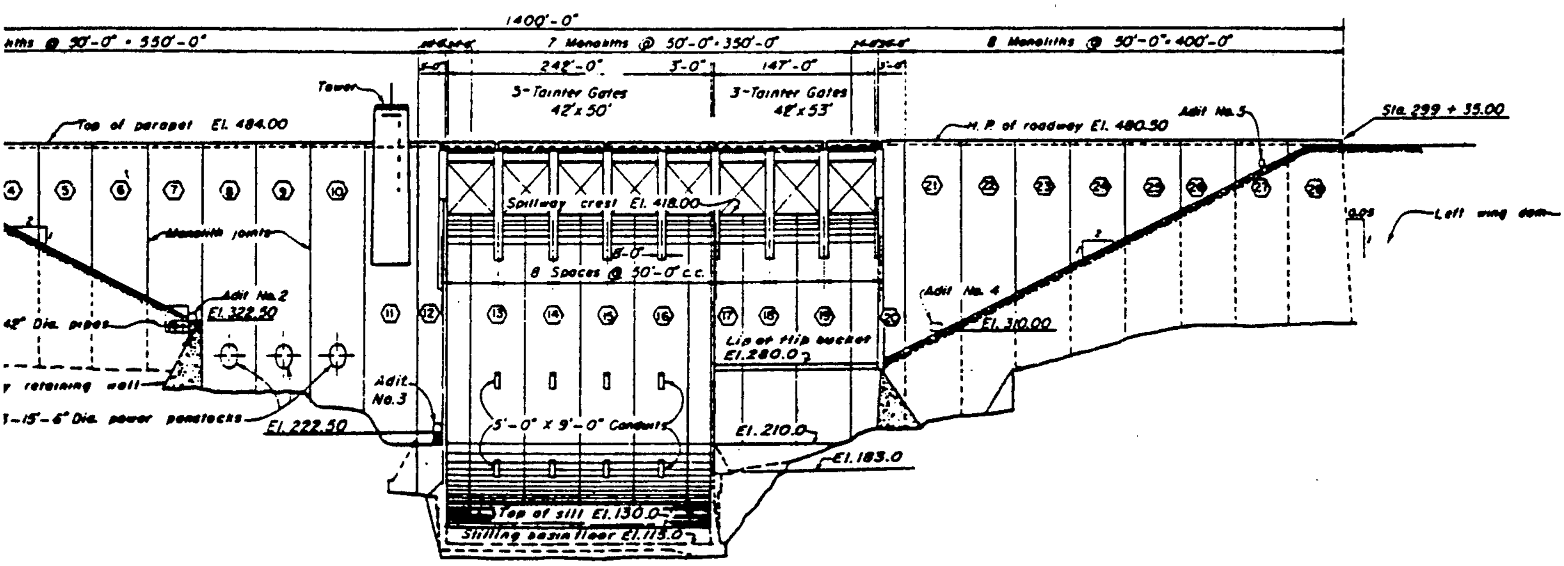
MA
CONCR
DOWN



NIMBUS DAM - UPSTREAM ELEVATION

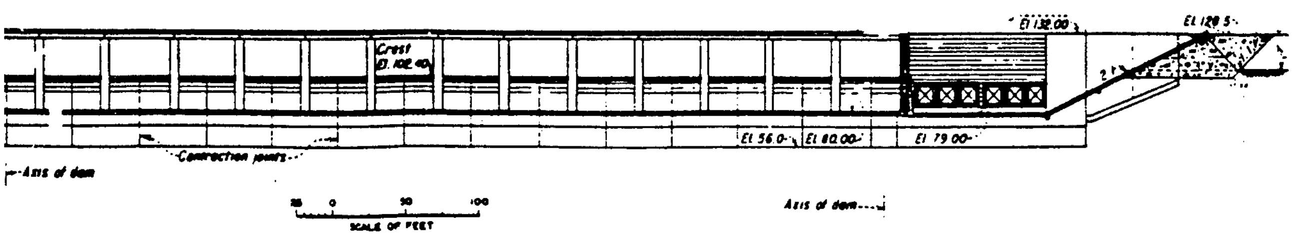


MAIN FOLSOM DAM – DOWNSTREAM ELEVATION

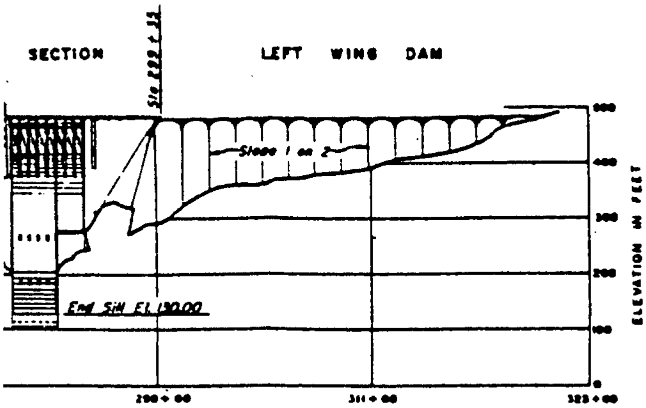


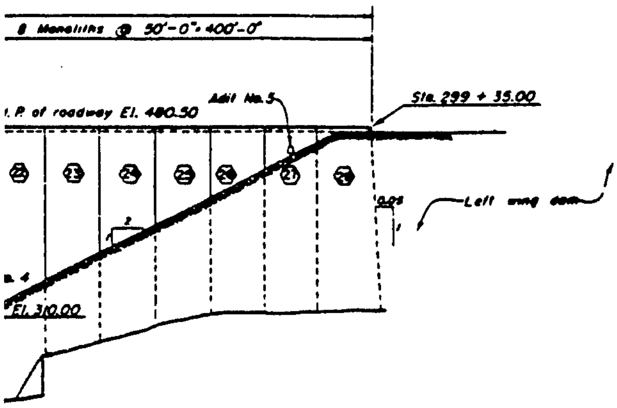
MAIN FOLSOM DAM
CONCRETE RIVER SECTION
DOWNSTREAM ELEVATION

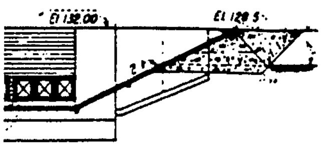
SCALE IN FEET



NIMBUS DAM – UPSTREAM ELEVATION



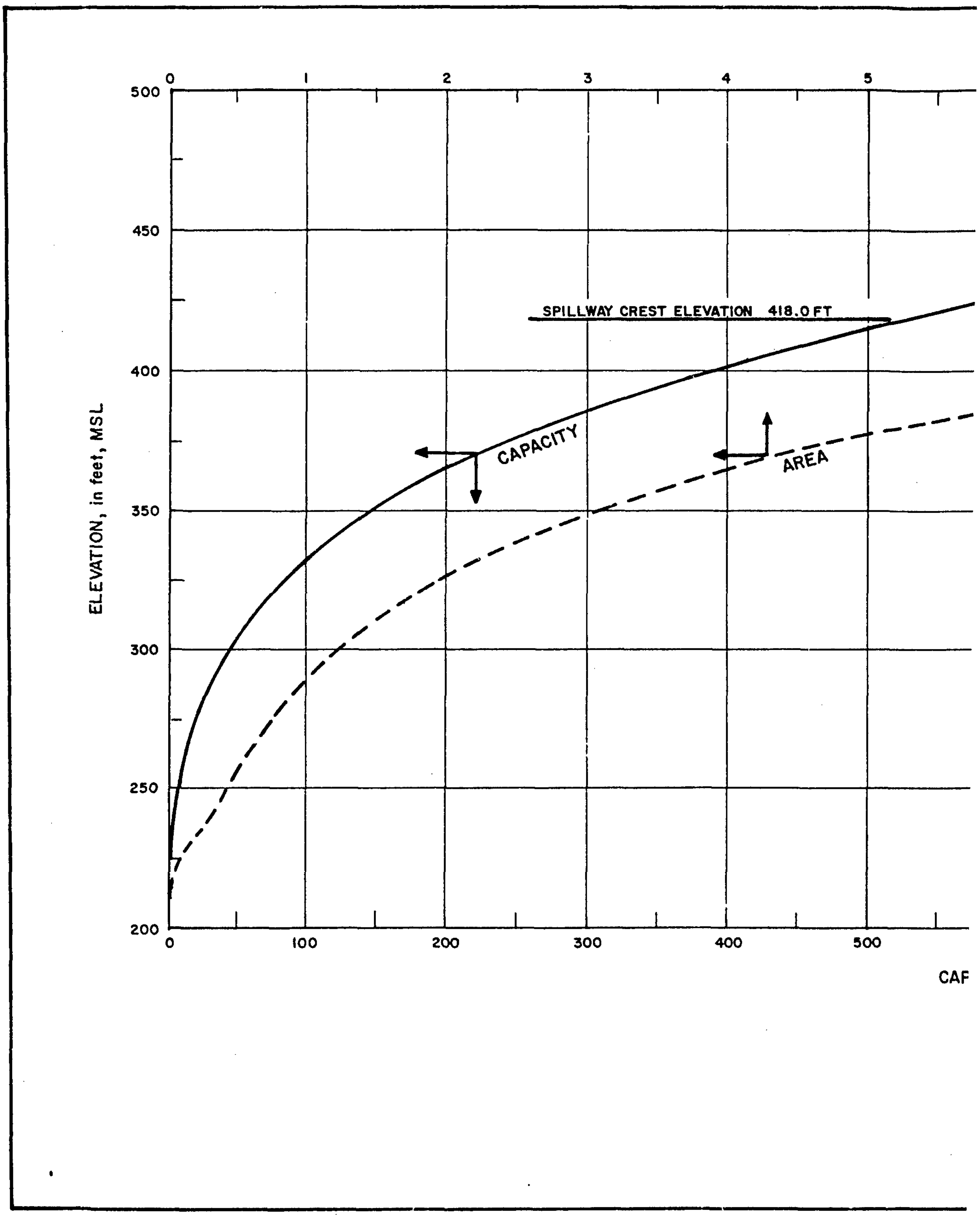




FOLSOM DAM AND LAKE
AMERICAN RIVER, CALIFORNIA

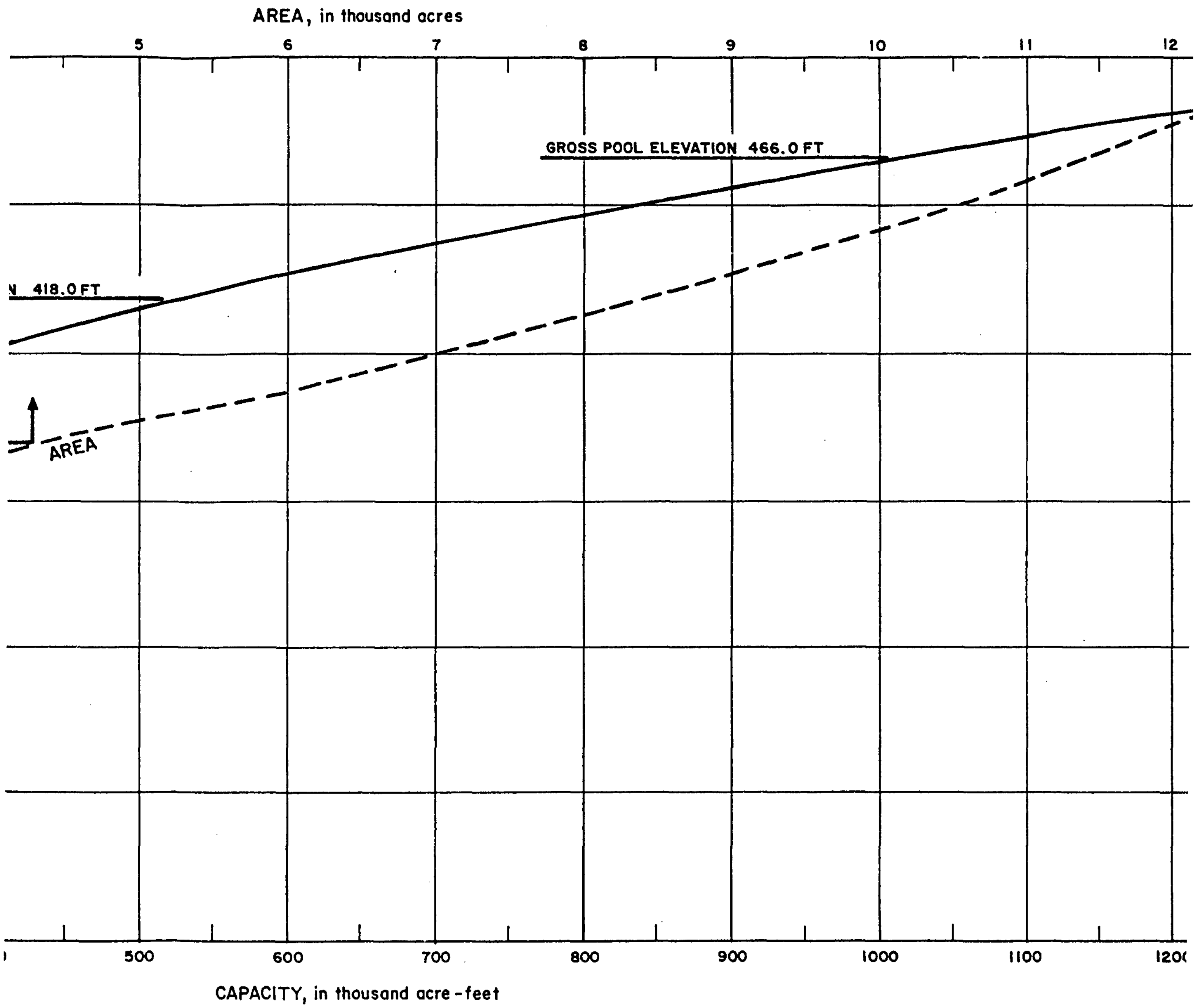
FOLSOM AND NIMBUS
DAM ELEVATIONS

U.S. ARMY CORPS OF ENGINEERS
SACRAMENTO DISTRICT



0
1
2
3
4
5
500
450
400
350
300
250
200
0
100
200
300
400
500
CAF
ELEVATION, in feet, MSL
SPILLWAY CREST ELEVATION 418.0 FT
CAPACITY
AREA

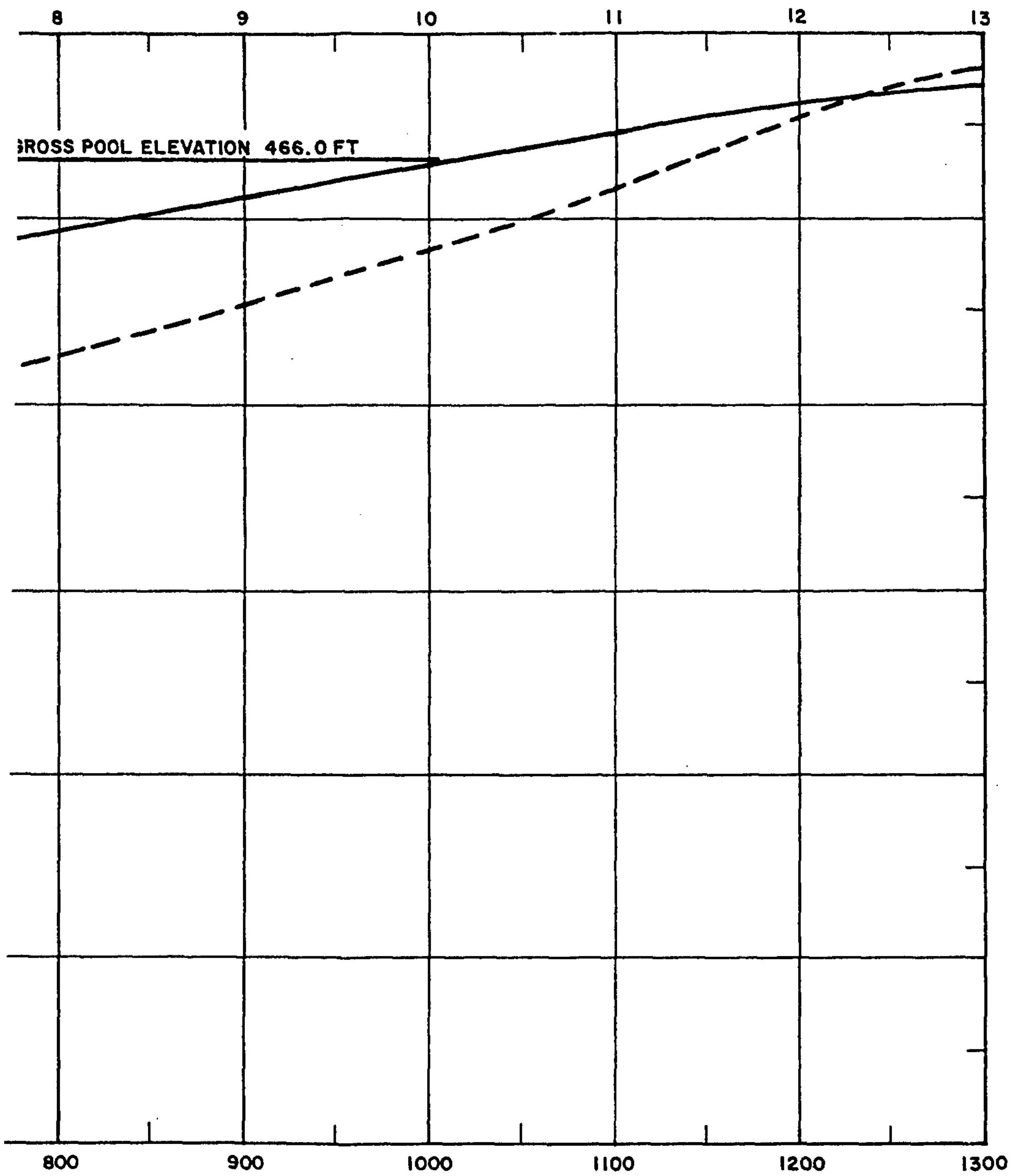
1



FOLSOM
AMERICAN I

AREA AND C

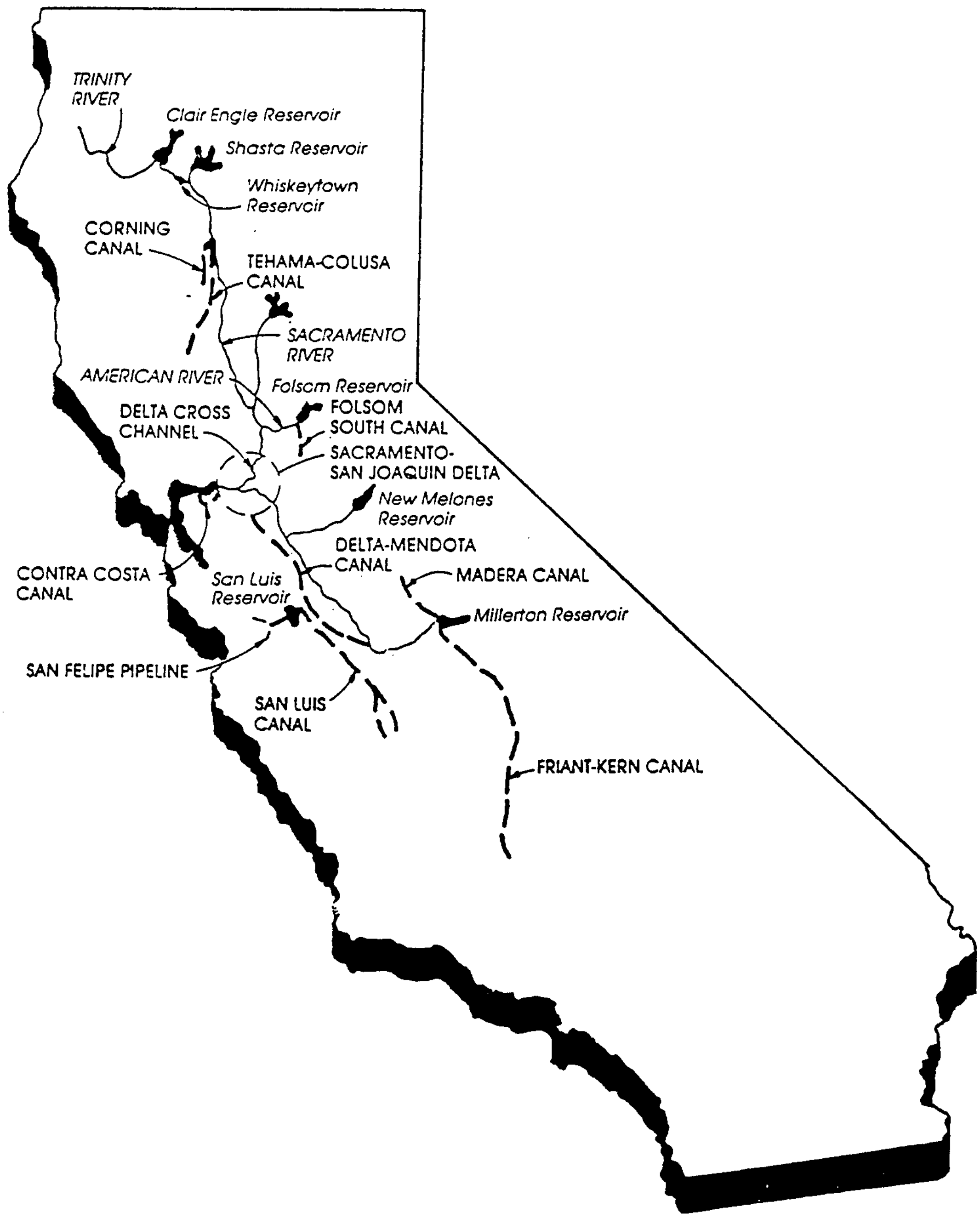
U.S. ARMY CC
SACRAM



FOLSOM DAM AND LAKE
AMERICAN RIVER, CALIFORNIA

AREA AND CAPACITY CURVES

U.S. ARMY CORPS OF ENGINEERS
SACRAMENTO DISTRICT

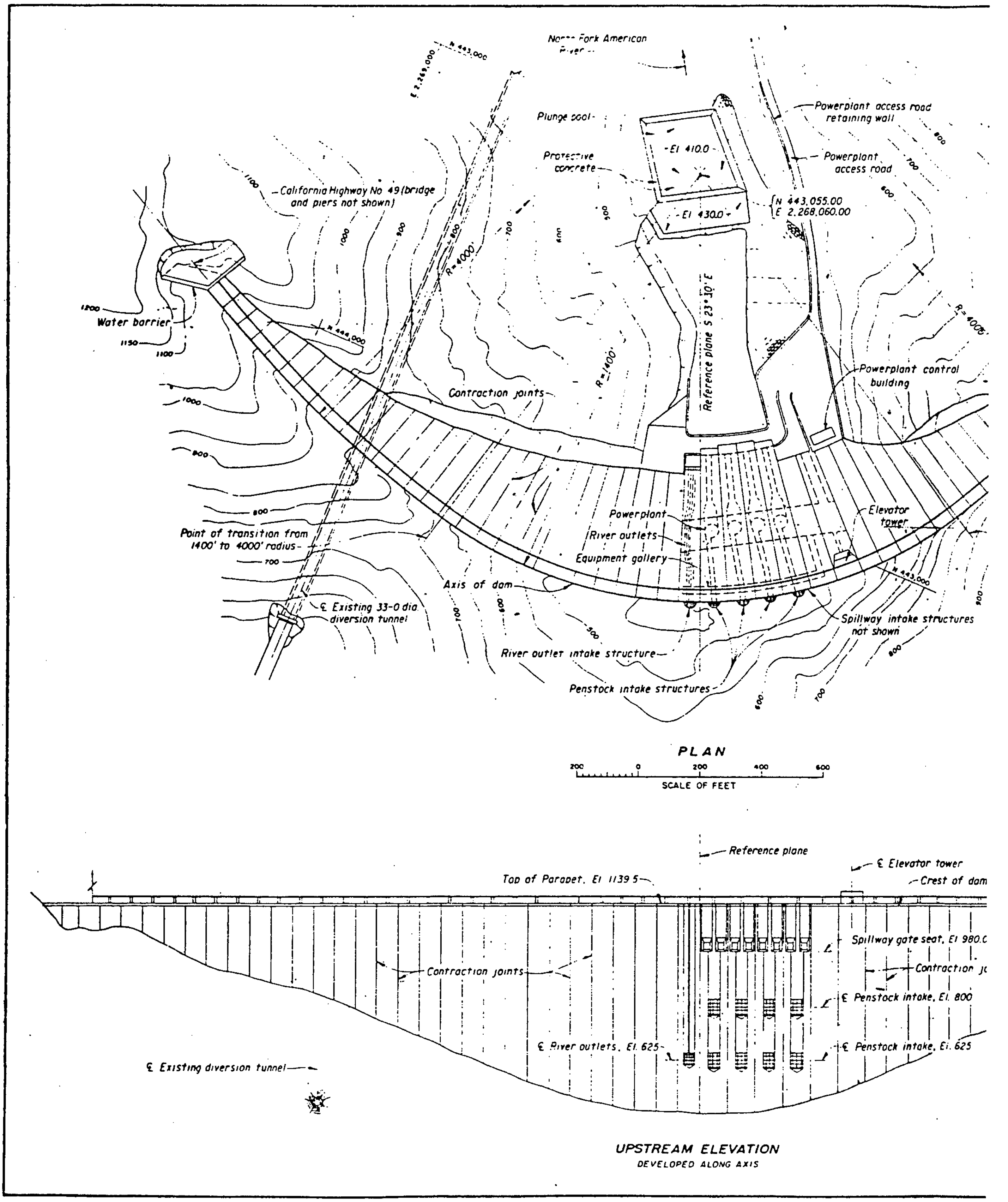


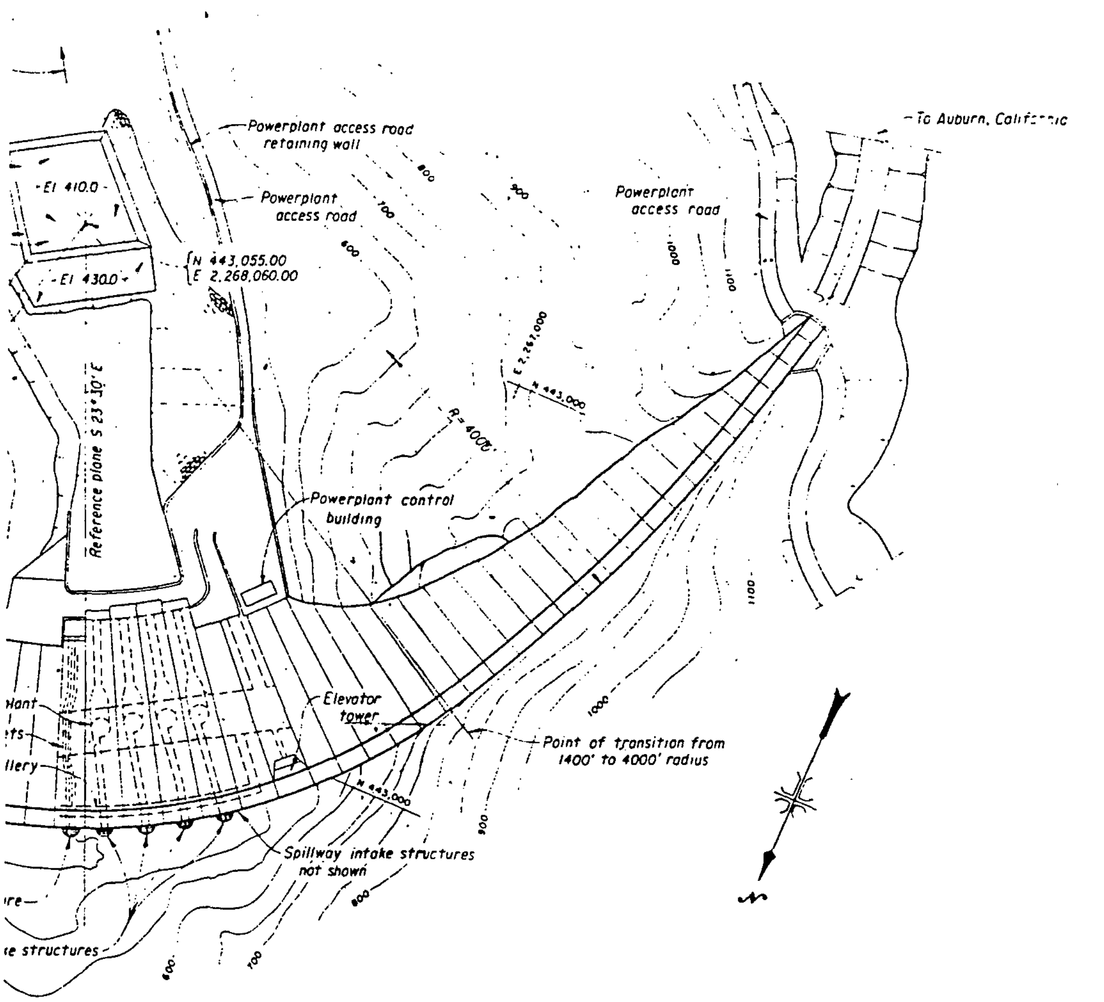
AMERICAN RIVER WATERSHED INVESTIGATION
CALIFORNIA

CENTRAL VALLEY PROJECT

SACRAMENTO DISTRICT, CORPS OF ENGINEERS
DECEMBER 1991

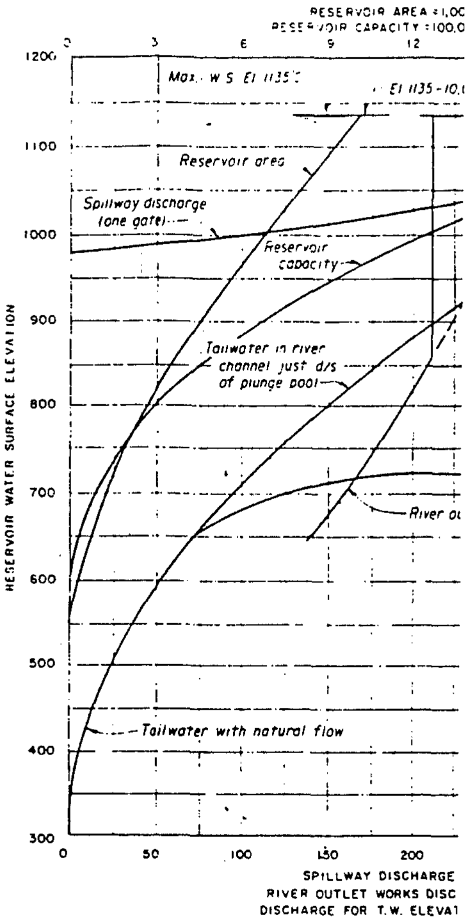
PLATE I-4


North Fork American River
Plunge pool
Protective concrete
El 410.0
El 430.0
Powerplant access road retaining wall
Powerplant access road
N 443,055.00
E 2,268,060.00
California Highway No 49 (bridge and piers not shown)
Water barrier
Reference plane S 23°30' E
R=4000'
R=1400'
Contraction joints
Powerplant control building
Powerplant
River outlets
Equipment gallery
Elevator tower
Point of transition from 1400' to 4000' radius
Axis of dam
Existing 33-0 dia. diversion tunnel
Spillway intake structures not shown
River outlet intake structure
Penstock intake structures
PLAN
SCALE OF FEET
Reference plane
Elevator tower
Top of Parapet, El 1139.5
Crest of dam
Spillway gate seat, El 980.0
Contraction joints
Penstock intake, El. 800
River outlets, El. 625
Penstock intake, El. 625
Existing diversion tunnel
UPSTREAM ELEVATION
DEVELOPED ALONG AXIS



PLAN

200 400 600
SCALE OF FEET



TAILWATER, AREA, CAPACITY AN

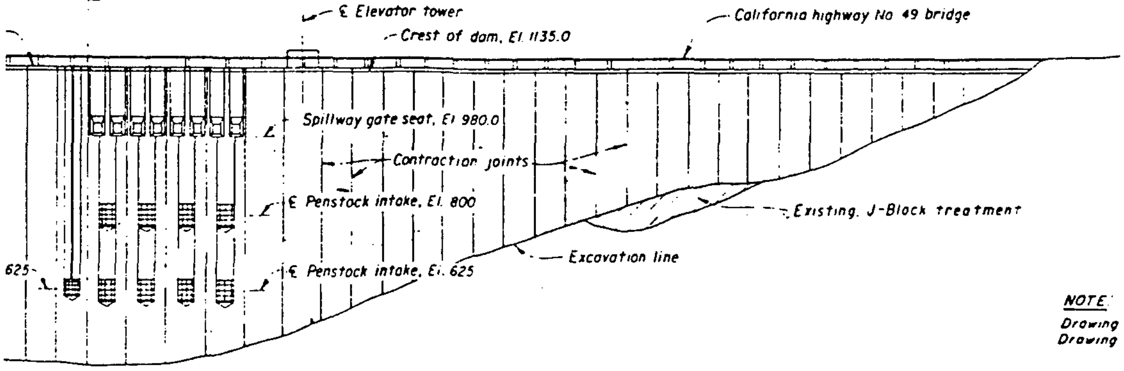
RESERVOIR CAPACITY

PURPOSE	ELEVATION
Surcharge	1131.4 to 1
Joint use	1083.1 to 1
Active conservation	816.5 to 1
Inactive	616.5 to
Dead	Streambed to
Total reservoir	

A surcharge of 36,000 a.f (Maximum W.S. E joint use capacity in combination with a c.f.s. is provided to protect against the a peak of 500,000 c.f.s. and a 5 day volume

*Maximum flood control space. Minimum fl with bottom of control pool at El. 1097.2 . can be shifted to Folsom Reservoir.

**Includes 25,800 a.f allowance for 100 yea stream and El. 1131.4, but excludes 36,0 1,300 a.f sediment above El. 1131.4

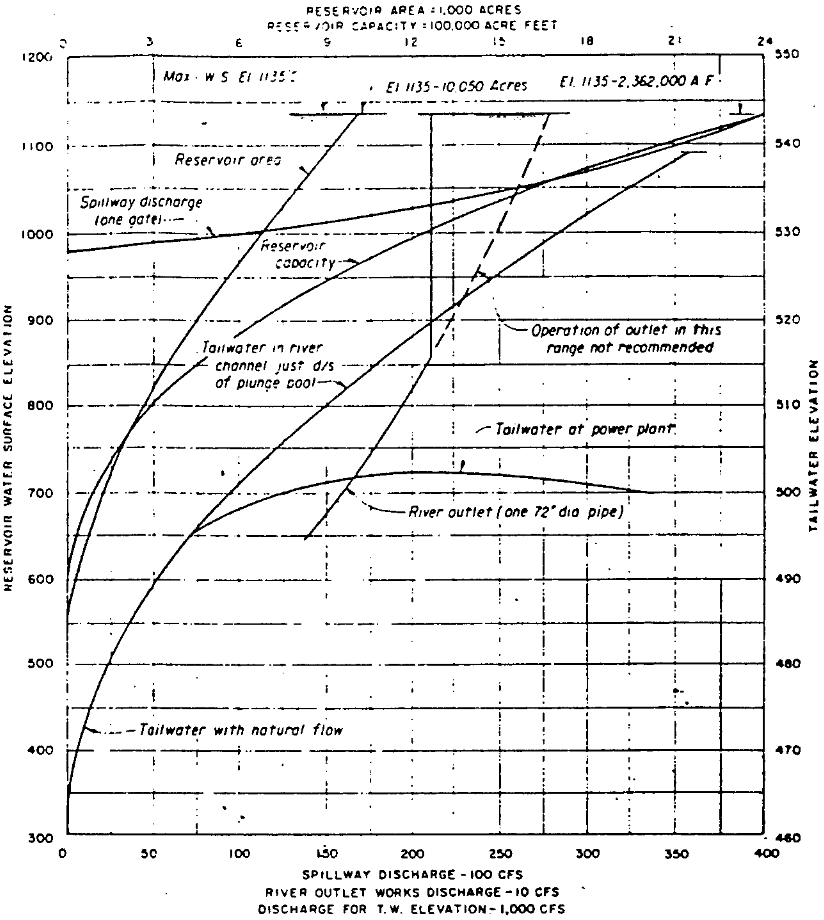


STREAM ELEVATION
DEVELOPED ALONG AXIS

NOTE:
Drawing adopted from U.S. Bureau of Reclamation, Drawing 859-D-2731, dated August 1, 1980

C

To Auburn, California



TAILWATER, AREA, CAPACITY AND DISCHARGE CURVES

RESERVOIR CAPACITY ALLOCATIONS

PURPOSE	ELEVATIONS	CAPACITY ACRE-FEET
Surcharge	1131.4 to 1135	36,000
Joint use	1083.1 to 1131.4	450,000*
Active conservation	816.5 to 1083.1	1,516,000
Inactive	616.5 to 816.5	331,000
Dead	Streambed to 616.5	29,000
Total reservoir		2,326,000**

A surcharge of 36,000 a.f (Maximum W.S. El. 1135) plus 450,000 a.f. in joint use capacity in combination with a spillway discharge of 327,000 c.f.s. is provided to protect against the inflow design flood which has a peak of 500,000 c.f.s. and a 5 day volume of 1,700,000 a.f..

*Maximum flood control space. Minimum flood control space is 25,000 a.f with bottom of control pool at El. 1097.2. 125,000 a.f. "floating" pool can be shifted to Folsom Reservoir.

**Includes 25,800 a.f allowance for 100 year sediment deposition between stream and El. 1131.4, but excludes 36,000 a.f. surcharge and 1,300 a.f. sediment above El. 1131.4

9 bridge

ck treatment

NOTE:
Drawing adapted from U.S. Bureau of Reclamation, Drawing 859-D-2731, dated August 1, 1980

BECHTEL
SAN FRANCISCO

EVALUATION OF AUBURN DAM

MILE 20.1
CG-3 PLAN AND ELEVATION

JOB No.	DRAWING No.	REV.
17535		

American River Watershed Investigation, California

APPENDIX J

Damsite Selection

DAM SITE SELECTION APPENDIX

CHAPTER I - INTRODUCTION

1. Purpose and Scope. - The Corps of Engineers is currently conducting a feasibility study along the North Fork of the American River. The study examines potential flood control improvements along the American River Watershed. A peak-flow flood control facility ("dry dam") on the North Fork of the American River will be evaluated with respect to operation of Folsom Dam. In 1967 the Bureau of Reclamation began work on the Auburn Dam Project at River Mile 20.1, located on the North Fork of the American River (Plate 1). Construction proceeded on the keyways, foundation, cofferdam, spillways, and outlet works until work was halted in August 1975 after the Oroville, California, earthquake. The upstream cofferdam failed in 1986 when flood waters overtopped the dam. The feasibility study is primarily scoped to evaluate the potential for a single-purpose flood control reservoir at the Bureau of Reclamation Auburn Dam site. The purpose of this appendix is to briefly evaluate the best practical and economical dam site for a single-purpose flood control dam located on the North Fork of the American River. This appendix describes the characteristics of four potential dam sites and compares the most likely alternative site (River Mile 19.0) with the existing Auburn Dam site (River Mile 20.1). Comparisons are made with respect to location, geology, construction costs, dam design, and Highway 49 relocation impacts.

Dam site selection evaluations were carried out early in the feasibility study. The design specifications presented in this appendix are preliminary figures only. Subsequent revisions to the Probable Maximum Flood (PMF) led to design modifications. Consequently, the design specifications shown in this appendix are different from the final design shown in Appendix N. Upon review it was found that these design differences did not affect site selection.

Cost estimates and work schedules were prepared and evaluated for each of the sites. It was assumed that a flood control dam at either site would have nearly the same detention space and would provide nearly identical flood control benefits. The cost estimates and flood control benefits provided are for dam site comparison purposes only and are not updated to current price levels. However, it was assumed that as these values increased they would retain the same comparison ratios. Updated cost estimates and benefits can be found in the Economics Appendix (Appendix c).

2. <u>Study Area Description</u>

The American River watershed covers an area of about 2,100 square miles in Northern California (Plate 1). It lies northeast of the City of Sacramento and drains the western slope of the Sierra Nevada. It includes portions of Placer, El Dorado, and Sacramento Counties. The potential dam sites evaluated for this appendix were all located in a narrow reach of the American River extending from the upper end of Folsom Reservoir, upstream to the confluence of the Middle and North Forks of the river.

a. <u>Regional Geology</u>. - The alternative dam sites are located in the western foothills of the central Sierra Nevada Mountains. The Sierra Nevada is a highly asymmetric mountain range having a long gentle western slope and a high steep eastern escarpment. It ranges from 50 to 80 miles wide, is about 400 miles long, and trends northwesterly. The alternative dam sites lie within a portion of these foothills. The geologic history of this area is very complex. One explanation involves plate tectonic concepts. The North American plate converged with the Pacific plate, resulting in the formation of the Foothills Fault system. During the Mesozoic Era this region went through several periods of intense crustal deformation. The present drainages have eroded through the foothills area. The Sacramento District's Geologic Evaluation of Alternative Dam Sites, dated January 1989, describes the Foothills Fault system.

The Geologic Evaluation of Alternative Dam Sites report also notes that the structural relationships of the Maidu East shear zone and faults in the foundations of the alternative dam sites may be different from that of the River Mile 20.1 dam site and subject to different displacement parameters. The dam sites are located in a region of relatively low to moderate seismicity. Historically, occasional tremors have been felt in the Auburn area. The tremors, however, have resulted from distant earthquakes in regions of higher seismicity. Examples include the April 1906 San Francisco earthquake (Richter magnitude 8.25), approximately 110 miles west of Auburn, and the September 1966 Truckee earthquake (magnitude 5.8), approximately 65 miles east of Auburn.

The largest earthquakes recorded along the Foothill Fault System since records have been kept (1850) were the 1940 Oroville event (magnitude 5.7), approximately 18 miles north of Lake Oroville, and the August 1975 Oroville event (magnitude 5.7), approximately 7 miles south of Oroville.

Geologic evidence gathered in the vicinity of Oroville Dam and the Auburn River Mile 20.1 dam site, following the August 1975 Oroville event, has established a precedence for considering the

Foothills Fault system to be active. Faults within a 2-mile radius of the Auburn dam sites are considered to be capable of generating an earthquake of magnitude 6.5.

Seismic ground-motion parameters and a magnitude of 6.5 were established for the River Mile 20.1 dam site by the Secretary of the Interior in July 1979 and could produce a potential 9-inch surface displacement. These parameters can probably be extrapolated to other alternative dam sites in the proximity of the River Mile 20.1 dam site.

b. History of Auburn Dam. - The Auburn-Folsom South Unit, Central Valley Project, was authorized by Congress in 1965 under Public Law 89-161. A dam, a reservoir, and a powerplant located on the North Fork American River near Auburn, California, were principal features of the project, as well as a 69-mile canal extending southward from the existing Nimbus Reservoir. The U.S. Bureau of Reclamation conducted feasibility studies of other types of dams and selected a double-curvature concrete arch dam at River Mile 20.1. Construction for the 690-foot-high dam began in 1967, and a 2,400-foot-long, 33-foot-diameter diversion tunnel was completed in 1972. Construction of a cofferdam upstream of the construction site was completed during 1975; 3 years later the cofferdam was raised 15 feet. Extensive excavation was also completed for the keyways and foundation treatment. The Oroville, California, earthquake occurred in August 1975 about 50 miles north of the Auburn Dam site. Surface cracking was observed on the northwest extension of the Bear Mountain Fault, a portion of which passes near the Auburn Dam site. This fault movement raised questions as to the ability of the proposed dam at Auburn to withstand seismic forces. The Secretary of the Interior halted construction on Auburn Dam in August 1975. The Bureau of Reclamation undertook extensive geologic studies to ascertain the ability of the arch dam to resist shaking and ground movement. In 1980, the Secretary of the Interior reported that the proposed Auburn Dam was seismically safe.

A joint State-Federal Auburn Dam Task Force, consisting of 17 non-Federal entities and the Bureau of Reclamation, expressed interest in a new cost-shared project. In 1985, the California Department of Water Resources evaluated an alternative concrete gravity dam design. The purpose of the study was to determine if there is a less costly option that could provide the same level of water supply, power generation, and flood control. The California Department of Water Resources recommended a straight axis concrete gravity dam at River Mile 20.1 because of work already completed at this site and the amount of geotechnical information available.

In 1986, the Bureau of Reclamation and the California Department of Water Resources requested the Corps of Engineers to review and update the American River hydrology, determine areas of potential flooding and flood damages, review and update alternative flood control measures, and reevaluate the flood control benefits of alternative measures. This study was completed in 1988 and documented in the Corps of Engineers "Reconnaissance Report, American River Watershed Investigation, California." The report concluded that a severe flood threat exists for about 350,000 people who live along the lower American River and in the Natomas area.

Currently, the State of California is the non-Federal sponsor of the ongoing American River Watershed Investigation feasibility study.

3. Pertinent Studies and Reports. - The California Department of Water Resources report entitled "Final Report in the Evaluation of the Auburn Dam Project," dated November 1985, evaluated the Auburn Dam Project as proposed by the U.S. Bureau of Reclamation. Items evaluated were:

(1) Auburn Dam and power facilities
(2) Potential dam sites along the American River
(3) Relocation of Highway 49
(4) Non-Federal agency project

The report was used herein as a reference for potential dam sites and possible Highway 49 relocation alignments.

The Bureau of Reclamation prepared a report entitled "Auburn Dam Report - Auburn Dam Alternative Study," dated July 1987. The report presents data and information on possible alternatives for the completion of Auburn Dam. Costs and alternatives were evaluated with respect to further Bureau of Reclamation participation in the project.

The Corps of Engineers "Reconnaissance Report, American River Watershed Investigation, California" was completed in January 1988. The report concludes that there is a serious flooding problem along the lower American River and in Natomas and that there is an economical solution to the flooding problem. It also recommended that a feasibility study proceed for the mainstem American River and Natomas. The study was used for background and evaluating potential river site locations.

The Corps of Engineers also prepared a report entitled "Sacramento River Flood Control System Evaluation, Initial Appraisal Report - Sacramento Urban Area," dated May 1988. The report presents study findings for the Sacramento River Flood Control Project, Inspection of Completed Works, and Sacramento River Flood Control System Evaluation. The report also presents justification for remedial repairs for approximately 32 miles of levees within the Sacramento urban area based on economic and public safety criteria. The study was used herein as background reference.

The City of Sacramento, Department of Public Works, Flood Control and Sewer Division, prepared a report entitled "City of Sacramento Flood Control Status Report" dated October 1988. This status report presents an overview of the flood control facilities protecting the city and greater Sacramento area.

The Sacramento District Corps of Engineers prepared a report entitled "Geologic Evaluation of Alternative Dam sites," dated January 1989. Pertinent geologic features were evaluated with respect to construction of a dam at four sites along the American River.

A Corps of Engineers study entitled "Concrete Materials and Roller Compacted Concrete Dam Considerations" was completed in January 1989. This study provides information on concrete materials, material properties, design and construction considerations, and preliminary dam sections for four alternative gravity dam sites near Auburn, California. The four sites studied were River Mile 19.0, 19.2, 20.1, and 22.1.

A Corps of Engineers report entitled "Auburn Dam Geotechnical Reconnaissance Report," dated February 1989, provided data for feasibility level cost estimates.

CHAPTER II - POTENTIAL SITE IDENTIFICATION

After authorization of the Auburn-Folsom South Unit of the Central Valley Project in 1965, the Bureau of Reclamation began investigating potential dam sites. Sites were evaluated with potential capacity to provide water supply, flood control, power, and instream flow. Site reaches investigated by the Bureau of Reclamation, State of California, and Corps of Engineers in the Upper American River Basin were Granite Canyon, Giant Gap, Growlersburg, Salmon Falls, Alder, and the Auburn vicinity. These potential sites are listed in Table 1.

TABLE J-1

POTENTIAL RESERVOIR SITES IN THE UPPER AMERICAN RIVER BASIN

SITE	STREAM	DRAINAGE AREA	AVERAGE ANNUAL RUNOFF (ac-ft/yr)	RESERVOIR STORAGE CAPACITY (ac-ft)
Granite Canyon	North Fork	96	226,000	300,000
Giant Gap	North Fork	200	396,000	650,000
Growlersburg	Middle Fork & Canyon Road	12	13,900	17,500
Salmon Falls	South Fork	807	940,000[1]	200,000[2]
Alder	South Fork & Alder Creek	19	18,600	80,000
Auburn	North Fork & Middle Fork	982	1,486,000	2,300,000

1/ Does not include adjustments for upstream regulation.
2/ Maximum capacity which will not inundate gold discovery site at Coloma.

Most of these sites were eliminated from further consideration due to potential impacts or limited size and locations. The Giant Gap and Granite Canyon sites could provide some flood control; however, both sites have now been included in State and Federal Wild and Scenic River Systems. The Growlersberg site could control only about a 12-square-mile area. On the South Fork of the American River, the Alder site is also very small, controlling only 19 square miles of watershed. The Salmon Falls site is restricted because a reservoir exceeding 200,000 acre-feet would inundate the Coloma historical gold discovery site. The most practical location for an upstream reservoir with a storage capacity large enough to provide 200-year level of flood protection appears to be on the North Fork of the American River below the confluence of the North and Middle Forks near Auburn.

After reviewing and evaluating previous studies, the Bureau of Reclamation and the State of California identified the American River Canyon as the most viable reach for a large dam and reservoir. This appendix is limited to the evaluation of four potential American River dam sites (previously identified by the State of California and the Bureau of Reclamation) as well as the No Action, or No Project alternative as it will be called in this report, because even if none of the sites are selected, restoration will still be required at the existing Bureau of Reclamation dam site located at River Mile 20.1.

4. Site Identification, Geology, and Foundation Conditions. - Alternative dam sites were narrowed to four based on studies by the California Department of Water Resources and the Bureau of Reclamation. These sites are River Mile 22.1, 20.1, 19.2, and 19.0. The locations are shown on Plate 2.

The River Mile 22.1 site is located 2 miles upstream of the Bureau of Reclamation Auburn Dam site (River Mile 20.1) in a narrow canyon on the North Fork of the American River. Access to the site is poor. Presently there is no access to the left abutment. Access to the right abutment is limited to Highway 49, which crosses high on the abutment, and an abandoned narrow gauge railroad grade low on the abutment. No geotechnical exploration investigations have been conducted above the riverbed, except on the right abutment. Riverbed investigations determined that the foundation rock is weathered and fractured, and a significant amount of serpentinized schist is located below the site on the right side of the river. Numerous sets of joints could cause problems during construction and would require extensive grouting. Explorations by the Bureau of Reclamation were halted when a large landslide and a small fault were detected in the right abutment.

The River Mile 20.1 site is the Bureau of Reclamation Auburn Dam site located southeast of the city of Auburn and northeast of the Sacramento metropolitan area. Considerable work has been completed at this site. The site is located on the North Fork of the American River. Site access and site clearing of construction areas have been completed. Approximately 12 miles of access roads have been completed. Some roads may require repair but many are still in use. The foundation and slope stabilization were completed during construction preparation for the Bureau of Reclamation concrete-arch dam. Foundation exploration and investigations are extensive. The Bureau of Reclamation completed mapping, trenching, drilling, test tunnels, rock mechanics, and fault and seismic studies for the dam site. During construction of the access roads and foundation excavation, over 30 small to large landslides were removed or stabilized.

The River Mile 19.2 site is located 0.9 miles downstream of the Auburn site on the North fork of the American River. Site access is limited on the left abutment and consists of old dozer roads used for exploration. Portions were washed away during the 1986 rains. The right abutment access consists of the powerplant road. No site clearing has been completed, and the construction work area for the Auburn site would have to be used due to the narrow canyon at the mile 19.2 dam site. Drilling revealed a deep block slide and a shallow slide on the left side of the dam. Excavation to a depth of 120 feet would be required to remove the deep slide. A cofferdam below the dam would be required to prevent backwater from Folsom Reservoir inundating the construction site. Also, a diversion dam would be necessary to divert streamflows from Knickerbocker Canyon away from the construction site. The foundation exploration consisted of about 30 drill holes and some trenching. No rock mechanics testing or test tunnels were completed. The geologic mapping is also incomplete. The right abutment has numerous shear zones, dikes, variable joint patterns, and small faults. Excavation to depths of approximately 30 feet and 15 feet would be required in the right abutment and foundation, respectively. Extensive grouting, to a depth of about 200 feet, would be required.

The River Mile 19.0 site is located 1.1 mile downstream of the Auburn site on the North Fork of the American River. No site access or site clearing has been completed at this site. This site is similar to the River Mile 19.2 site and would require the use of the River Mile 20.1 construction areas. Cofferdams above and below the dam would be required as with site 19.2. Foundation investigations have partially been completed upstream of the right abutment. No exploration or drill holes have been completed on the left abutment. Dam foundation preparation will require removal of landslides and weathered rock to about 30 feet. A 200-foot-deep grout curtain will be required to help prevent seepage under the dam. Two faults passing through the right abutment were mapped by the Bureau of Reclamation. Further mapping and exploration is necessary to determine if there are any additional faults.

The seismic studies prepared for the Auburn Dam site are applicable for the 19.0, 19.2, and 20.1 sites. Further seismic study would be required for the 22.1 site.

5. Initial Site Screening. - Listed below in Table 2 are the primary characteristics of the four potential dam sites. With respect to Table 2, it is apparent that significant exploration, design, and construction have been completed at the River Mile 20.1 site. Approximately $233 million has been expended by the Bureau of Reclamation in planning, design, and construction activities for a large dam at this site. There is strong local support for locating a proposed flood control dam at River Mile 20.1 in order to maximize utilization of already completed work by the State of California and the Bureau of Reclamation. Alternative dam sites at River Mile 19.2 and River Mile 22.1 were rejected from further consideration due to identification of faults in the abutments. Therefore, further analysis was limited to a comparison of potential flood control dams located at River Mile 19.0 and River Mile 20.1.

Insert Table 2 American River Dam Site Evaluation Screening

Insert Table 2 (cont.)

6. Description of Dam Site. - Dam site 19.0 is located 1.1 miles downstream of the Bureau of Reclamation 20.1 dam site. A rolled embankment and a roller compacted concrete dam were evaluated for each site. Both dams would be about 460 feet high, with a crest length of 1,500 feet. A 200-year level of flood protection would be provided. A gross pool of 535,000 acre-feet and a maximum pool of 783,000 acre-feet would be created. The spillways were designed to pass a design flood of 783,000 cfs. The spillway of the rolled embankment dam would consist of a 500-foot-wide concrete crest with an unlined chute. The outlets would consist of two 24-foot-diameter tunnels. The maximum discharge through both tunnels would be 89,000 cfs. The tunnels would be used for diversion during construction and flood control. Two cofferdams would be required, a 274-foot upstream diversion dam and a 40-foot downstream dam to prevent Folsom Reservoir tailwater from inundating the construction area. Total estimated foundation excavation for the embankment dam would be about 1,750,000 cubic yards and 11,560,000 cubic yards of fill. A diversion structure would divert Knickerbocker Creek streamflow around the construction site. The roller compacted concrete dam would require about 1,090,000 cubic yards of foundation excavation and 2,735,000 cubic yards of roller compacted concrete. The emergency spillway would consist of a 300-foot-wide crest with a design flood peak flow of 648,900 cubic feet per second. The outlets through the Dam would consist of three levels of sluices. The lower level would require bulkhead gates for inspection. The middle and upper level sluices would be ungated and protected by trash racks.

Dam site River Mile 20.1, the existing Bureau of Reclamation site, is located south of Auburn, California. The proposed rolled embankment or roller compacted concrete dam would be approximately 520-feet high, with a crest length of 2,700 feet. The gross and maximum pools would be 544,200 acre-feet and 868,000 acre-feet, respectively. The unlined 400-foot-wide spillway was designed to pass a peak floodflow of 631,600 cfs. The existing outlet diversion tunnel would require modification and two 15-foot-wide by 30-foot-high gate passages constructed for flow regulation. For the rolled embankment dam, a 300-foot-high upstream cofferdam would be required to divert water into the diversion tunnel. A small 50-foot-high cofferdam would prevent backwater from inundating the work area. Total foundation excavation would be about 4,900,000 cubic yards. Embankment fill for the dam and cofferdams would be about 21,034,000 and 4,483,000 cubic yards, respectively.

The roller compacted dam would require 5,900,000 cubic yards of foundation excavation and 2,735,000 cubic yards of roller compacted concrete. The emergency spillway would consist of an ogee weir - 350 feet long at the crest and 290 feet wide at the flip bucket. The spillway was designed for a 62-foot head and a design flood peak flow of 650,000 cfs. The existing diversion tunnel would be modified to a 30-foot-diameter concrete-lined tunnel with two 15-foot-wide by 30-foot-high intake gates. There would also be two 5-foot-wide by 9-foot-high sluices through the roller compacted concrete dam.

a. Highway 49 Considerations. - Highway 49 currently crosses the North Fork of the American River on a bridge at about River Mile 23.3. Construction of a dam at River Mile 20.1 or River Mile 19.0 would inundate this bridge and other portions of Highway 49. Prior Bureau of Reclamation plans called for a relocation of the highway across the crest of the Auburn Dam. A California Department of Water Resources study evaluated six potential Highway 49 relocation alternatives. Two of those alternatives crossed the Middle Fork upstream of the proposed dam sites. The other four crossed the North Fork on the crest of proposed dams at sites River Mile 22.1, 20.1 19.2, and 19.0, respectively. There are problems associated with plans to relocate Highway 49 across the top of any of the dams. Because the single-purpose dry dam would be lower than a multiple-purpose dam, there is inadequate distance needed for curves and road slopes. Therefore, an upstream high bridge on Middle Fork meeting projected California Department of Highways standards was selected (Plate 2). For this site selection analysis, the full cost of relocating Highway 49 was included as a project cost. Because the highway (as now formulated) will be upgraded from two to four lanes, future cost-sharing studies will be necessary to determine the final portion of the relocation to be included as a project cost.

b. Potential for Expansion. - River Mile 19.0 and 20.1 sites both have potential for expansion. The roller compacted concrete single-purpose flood control dam could be expanded to a multipurpose facility. The dam for a single-purpose, 200-year level of protection would provide storage of 544,000 acre-feet at the Auburn site (River Mile 20.1). This dam could be enlarged to store 2.3 million acre-feet; of this space, 620,000 acre-feet would be seasonally available for flood control. The Bureau of

Reclamation estimates that this project would also provide up to 350,000 acre-feet of firm annual water supply yield and about 610 GWH per year of hydropower. Capital cost of either the River Mile 19.0 or River Mile 20.1 dams could be reduced by adopting a staged-construction schedule wherein a smaller sized dam is constructed initially and subsequently raised when additional water and power are justified. If a staged-construction schedule were to be adopted, special provisions would need to be included in the initial design and construction. The powerplant would need to be located so as not to interfere with future construction. Also, the foundation and keyways should be large enough to receive the extra material and weight of the enlarged dam. Penstocks, outlet works, and spillways should be large enough to pass the maximum flows for the large multipurpose dam. Expansion of a roller compacted concrete dam would be relatively simple at either site. There would be little difficulty in bonding a new roller compacted concrete section to an older roller compacted concrete section. A good bonding surface would be established by constructing the initial downstream face with formed steps. For expansion of the structure, these steps would be cleaned, scarified, and treated with a bonding mortar before new roller compacted concrete is placed.

Expansion of a roller compacted concrete dam would require minimal foundation preparation; only the new downstream section would have to be prepared. The long crest length required for a multiple-purpose dam at the River Mile 19.0 site could have some impact on site selection. Due to the longer crest length, much more extensive foundation preparation would be required for a multipurpose dam at River Mile 19.0 than at River Mile 20.1. The unlevel terrain could also have an effect on design and modeling of a multipurpose dam at River Mile 19.0. The preliminary foundation cleaning already done for the River Mile 20.1 site would reduce the necessary foundation preparation for an expanded dam at this site.

c. Site Restoration Considerations. - There are three dam site restoration scenarios. They are (1) the No Project Alternative, (2) Dam Construction at River Mile 19.0, and (3) Dam Construction at River Mile 20.1.

Scenario 1 - If a dam is not built at either site, measures must be taken to restore the disturbed River Mile 20.1 site and close the Bureau of Reclamation field office located in Auburn. The first costs for this scenario, itemized on the Table 3, would be $62 million.

TABLE J-3

NO PROJECT SCENARIO COST ESTIMATE

ITEM	COST ($ million)
Remove existing cofferdam	12.9
Remove contractors service area	5.8
Plug diversion tunnel	1.3
Rehabilitate roads	9.7
Revegetate	1.9
Restore seismic areas	1.9
Prevent of water pollution	2.5
Subtotal	36.2
Contingency 25%	9.0
Subtotal	45.2
E&D - S&A (15%)	6.8
Site Restoration subtotal	52.0
Close USBR field office	9.6
No Project Total First Cost (rounded)	62.0

Scenario 2 - If construction of a dam at River Mile 19.0 is selected, only part of the above restoration measures will be necessary because some of the completed work at the upper site would be utilized at the lower site. Associated costs of this scenario would be about one-half the first scenario - approximately $28 million. Required work items would include the removal of the service area, plugging of the diversion, rehabilitation and revegetation of roads, restoration of disturbed areas, and water pollution prevention measures.

Scenario 3 - If construction of a dam at River Mile 20.1 is selected, only very minimal restoration would be required. The existing service area, diversion tunnel, and road system could be utilized. The existing breached cofferdam would be rebuilt and used in conjunction with the existing diversion tunnel to convey flows around the construction site.

d. Design and Construction Schedules. - Separate project schedules were developed for River Mile 20.1 and for River Mile 19.0, as shown in Plate 3. The schedules are based on the assumption that a single-purpose flood control dam would be built at either site. It should be noted that the project schedule is well defined for the River Mile 20.1 site. However, at the present stage of study, there is not enough geotechnical information to make a definitive determination as to the time required to complete project construction at the River Mile 19.0 site. This uncertainty is reflected on Plate 3 by use of dashed lines. The schedules shown with solid lines represent the critical path for construction of a roller compacted concrete dam at each site. A rolled embankment dam at either site would require an additional 6 months to construct. These schedules assume equivalent timing for authorization and funding. Preparation of the Feature Design Memorandum and Plans and Specifications will also require approximately the same time for either site. Differences in the schedule were primarily due to additional explorations, studies, and construction requirements. The schedules are briefly discussed below:

River Mile 20.1 - A minimal amount of geotechnical work would be required to explore and evaluate the dam axis not covered by previous explorations. It is estimated that construction time at River Mile 20.1 could be accelerated as a result of the existing work completed by the Bureau of Reclamation. Approximately 30 months will be required for construction of a roller compacted concrete dam. The project could be completed as early as 1996.

River Mile 19.0 - This site would require at least an additional year of geotechnical exploration to obtain necessary data. Also, an additional year would be required to develop and stabilize access roads and a diversion tunnel. Construction of a roller compacted concrete dam at this site would require approximately 42 months. Project completion could require up to 4.5 years longer than at River Mile 20.1. If no additional faults are encountered, the project could be completed by 2001.

The minimum time to project completion after feasibility studies are completed varies from 6 to 6.5 years for roller compacted concrete and rolled embankment dams, respectively, at River Mile 20.1. At River Mile 19.0, the time to completion would range from 10.5 to almost 12 years. Other factors such as authorization and funding delays, legal challenges, local concerns, and design changes could also delay these schedules.

e. First Costs. - Cost estimates were developed for both roller compacted concrete and rolled embankment dams at each site. Subsurface conditions are well known at River Mile 20.1. As a result, firm cost estimates were developed for the site. However, at River Mile 19.0, subsurface conditions are not fully known. Therefore, a cost estimates range was prepared to represent potential subsurface conditions. There is also a possibility that such substantial faulting will be encountered at River Mile 19.0 that the site would have to be abandoned and construction completed at River Mile 20.1. A summary of first costs is shown in the tabulation following:

SUMMARY OF FIRST COSTS

SITE/TYPE	FIRST COST ($MILLION)
River Mile 20.1	
Roller Compacted Concrete	349.7
Rolled Embankment	357.7
River Mile 19.0	
Roller Compacted Concrete	295.5 to 319.8
Rolled Embankment	294.1 to 296.2

Cost Estimates for the roller compacted concrete alternatives at River Mile 19.0 are based on 400-foot and 60-foot spacing of the construction joints, respectively. For the rolled embankment alternative, the more expensive condition would require a deeper cut-off trench and extra keyway excavation.

Table 4 displays a summary of the reconnaissance level cost estimates by category. Unit costs are based on October 1989 price levels and are for comparison purposes only.

Lands costs were estimated using a basic cost of $24 million for project lands and $2 million for Highway 49 relocation lands. Also, the cost of borrow area lands for the rolled embankment dam alternatives made total lands costs higher for this type of construction.

Relocations and utilities costs, estimated at $83 million, were used for each alternative. This included $80 million for the Highway 49 relocation, $2 million for relocation of Ponderosa Way, and $1 million for telephone and power line relocations.

Dam costs for all four alternatives at River Mile 19.0 include an extra $643,000 for diversion of Knickerbocker Creek. The diversion is required to prevent inundation of the construction area.

Engineering and design was increased from 12 percent to 14 percent for each cost estimate at River Mile 19.0. This is an increase of about $2 million for additional geotechnical exploration, studies, and evaluation, and for the design of additional features required at the site.

TABLE J-4

ALTERNATIVE COST ESTIMATES

SITE	ITEM NUMBER	DESCRIPTION	COST ($ million)
R.M. 20.1	01	Lands	26.00
Roller	02	Relocations and Utilities	83.00
Compacted	04	Dams	186.75
Concrete	30	Engineering and Design	32.37
	31	Supervision and Inspection	21.58
		Total	349.70
Rolled	01	Lands	26.80
Embankment	02	Relocations and Utilities	83.00
	04	Dams	192.75
	30	Engineering and Design	33.09
	31	Supervision and Inspection	22.06
		Total	357.70
R.M. 19.0	01	Lands	26.00
Roller	02	Relocations and Utilities	83.00
Compacted	04	Dams	137.92-157.83
Concrete	30	Engineering and Design	30.91- 33.70
	31	Supervision and Inspection	17.67- 19.27
		Total	295.50 319.80
Rolled	01	Lands	26.40
Embankment	02	Relocations and Utilities	83.00
	04	Dams	136.44-138.07
	30	Engineering and Design	30.71- 30.95
	31	Supervision and Inspection	17.55- 17.68
		Total	294.10-296.20

f. Risk and Uncertainty. - Major storms occurred in northern California during February 1986, causing record floodflows in the American River Basin. Folsom Dam and Reservoir, prior to this time, was believed to control flows up to the 120-year event. However, after these storms were analyzed and studies completed, Folsom Reservoir flood operation was found to be only capable of controlling about a 63-year flood event. Therefore, the probability of Folsom Dam overtopping and causing major flood damage is about 1 in 63 (or 1.6 percent) in any given year.

The number of people living in the area subject to flooding by the American River is about 350,000. A 100-year flood event could cause an estimated $7.5 billion in damages below Folsom Dam; a 200-year event nearly $11 billion.

A minimum of 7 years would be required to design and construct a dam at River Mile 20.1. At River Mile 19.0, it would take at least 12 years - 5 years more than the upper site. Using the 1.6 percent probability that flooding equal to or greater than a 63-year event will occur in any given year means that there would be at least an 11 percent risk of being flooded if a dam is constructed at the River Mile 20.1 site and at least a 19 percent risk of flooding if a dam is constructed at the River Mile 19.0 site.

Potential average annual benefits forgone could be used analogously to the risk of flooding prior to project completion. If the site at River Mile 19.0 is selected, the metropolitan Sacramento area would be at risk of serious flooding for an additional 5 years. Given that average annual benefits for either site are $61.9 million, this translates to over $300 million during the 5-year period, almost as much as the entire project cost at River Mile 20.1.

There is another aspect of risk and uncertainty associated with the selection of the River Mile 19.0 site; that is, the faulting conditions at the site are unknown. Cost estimates were made to show the cost of additional studies and work that would be required if additional faults are found. However, public sentiment and institutional constraints could dictate abandoning the site if major faults are found.

g. <u>Economic Evaluation</u>. - Project Costs To Date - The project cost to date for the River Mile 20.1 dam through September 30, 1987, are in excess of $233 million. Since the inclusion of these costs would not affect the outcome of this economic analysis, they were not included. A summary of these sunk costs is shown below (and includes about $10 million for lands and rights-of-way, most of which could be sold).

PROJECT COSTS TO DATE

Dam	$216,889,000
Recreation	5,668,000
Service Facilities	1,740,000
Fish and Wildlife	330,000
Permanent Operating Facilities	36,000
Powerplant	8,373,000
TOTAL	$233,036,000

Economic Costs - Total annual economic costs for roller compacted concrete and rolled embankment dams were compared for both sites. These costs consist of first costs, environmental mitigation costs, costs to restore the River Mile 20.1 site, interest during construction, and operation and maintenance costs.

Environmental studies of the River Mile 19.0 site are not yet complete; therefore, a preliminary estimate of $15,000 per acre disturbed by the dam footprint was used as the environmental mitigation cost at River Mile 19.0. Other environmental mitigation will be required, including that for disturbance to the area upstream of each dam to be inundated. Also, a rolled embankment dam for either site would necessitate the removal of borrow material from about 370 acres to a depth of 1 to 2 feet - destroying all vegetation and trees in the Knickerbocker area. The area is presently being studied as a potential recreation site. Since the environmental impacts of these two features are similar for both alternatives, no attempt was made to quantify them. No environmental mitigation or restoration were included in the River Mile 20.1 site estimate because previous work completed at the site would be utilized in a future project.

Restoration costs for the River Mile 20.1 site ($28.2 million as discussed in paragraph d.) were included for all River Mile 19.0 alternatives.

Interest during construction was also added for each alternative to determine the total investment cost since major benefits would accrue until project completion. Annual operation and maintenance costs of $38,000 were also included for each alternative to establish the total annual cost of each alternative. These costs are summarized in Table 5.

TABLE J-5

ECONOMIC SUMMARY
($ million, 1989 Prices, 8-7/8 percent Interest Rate)

Alternative	First Cost	Subtotal[1] w/Env Mit & Restoration	Interest During Construction	Total Investment Cost	Total[2] Annual Cost
RIVER MILE 20.1					
Roller Compacted Concrete	340.7	340.7	32.248	381.948	34.0
Rolled Embankment	357.7	357.7	38.672	396.372	35.2
RIVER MILE 19.0					
Roller Compacted Concrete	295.5-319.8	324.0-348.3	38.3-41.2	362.3-389.4	32.2-34.6
Rolled Embankment	294.1-296.2	323.5-325.6	44.4-44.6	367.8-370.2	32.7-32.9

1/ Environmental mitigation and River Mile 20.1 restoration costs included in subtotal for River Mile 19.0 alternatives.
2/ Includes operation and maintenance for each alternative.

The average annual flood control benefits for either site are approximately $61.9 million. This means that the benefit-cost ratios range from 1.8 for a rolled embankment dam at River Mile 20.1 to 1.9 for a roller compacted concrete dam at River Mile 19.0 (excluding mitigation for the reservoir inundation areas and borrow sites which would lower the benefit-cost ratios somewhat but not alter their relative cost effectiveness). Clearly, construction of a single-purpose flood control dam is economically justified at either site.

Due to unknown site conditions at River Mile 19.0 and the associated uncertainty of project costs for the site, the NED plan cannot be identified. Also, there are many factors involved in the site selection process which cannot be quantified using accepted NED procedures. These include the risk of serious flooding and potential for loss of life involved with delayed project completion and the uncertainty associated with the possibility of encountering major faults at the River Mile 19.0 site, which would force totally abandoning the site with construction already begun.

CHAPTER V - CONCLUSIONS

Although the potential least-cost alternative is a dam at River Mile 19.0, there is overwhelming evidence that the risks and uncertainties associated with selection of this site make it unfavorable to recommend. Not only would there be a serious flood threat and potential for loss of life in the metropolitan Sacramento area for an additional 5 years but also a firm first cost cannot be reasonably determined due to the unknown faulting conditions at the site. There is also the possibility of encountering faulting at River Mile 19.0 which would result in abandoning the site.

Therefore, it is concluded that construction of a single-purpose flood control dam at the existing River Mile 20.1 site is reasonable and prudent. The risks associated with selecting the alternative dam site are not warranted by the relatively small magnitude of potential savings. To the contrary, a change of project site at this point in time could result in significant increases of the total project cost.

American River Watershed Investigation, California

APPENDIX K

Hydrology

APPENDIX K

OFFICE REPORT JANUARY 1990

AMERICAN RIVER AND SACRAMENTO
METRO INVESTIGATIONS, CALIFORNIA

HYDROLOGY

US Army Corps
of Engineers
Sacramento District

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CHAPTER I - INTRODUCTION

1. **AUTHORITY** - This study was conducted under the authority of the Flood Control Act of 1962 (Public Law 87-874, dated October 23, 1962) as follows:

   "The Secretary of the Army is hereby authorized and directed to cause surveys for flood control and allied purposes, including channel and major drainage improvements, and floods aggravated by or due to wind or tidal effects, to be made under the direction of the Chief of Engineers, in drainage areas of the United States and its territorial possessions, which include the following named localities: Sacramento River Basin and streams in Northern California draining into the Pacific Ocean for purposes of developing, where feasible, multi-purpose water resource projects, particularly those which would be eligible under the provisions of title III of Public Law 85-5001."

2. **PURPOSE AND SCOPE** - The main purpose of this study is to determine the level of protection provided by the Sacramento River and American River Flood Control Systems. These Flood Control Systems include the Sacramento River from Ord Ferry to Snodgrass Slough and the American River from Nimbus to the Sacramento River. This determination became necessary after the large flood event of February 1986 heavily taxed the system. The 1986 flood produced higher flows and stages at some locations within the study area than any flood since the 1862 flood. This flood was extreme despite the construction of many upstream dams and flood control structures in the years since 1862.

   After this event, various planning studies were initiated. These studies required detailed hydrologic input to answer many questions which arose during and after the February 1986 event. To answer these questions, Planning Division coordinated various work order requests with Hydrology Section. Listed below are the main job items contained in these work order requests.

   Compare the 1986 event to design flows and stages.
   (see Table 3, page 8 and Charts 55 to 60)

   Compute the 100-, 200- and 400-year flood volumes at Fremont Weir
   (see Chart 11)

   Compute the 100-, 200- and 400-year stages at various locations.
   (see Charts 38 thru 43 and Table 22, pages 64-68)

   Compare the 1986 peak stages with the 100-year stages at various locations.
   (see Table 22, pages 64-68)

Compute the Standard Project Flood for the American River Basin (see Chapter III, Section 2E and Chart 7)

Develop Flow-Frequency curves for the American River (see Chapter III, Section 2D and Charts 4 and 5)

Compute the Probable Maximum Flood for Auburn Dam. (see Chapter VI, Section 5)

Compute the estimated sediment yield at the Auburn damsite. (see Chapter VI, Section 7)

These data were necessary to determine if the Sacramento and American Flood Control Systems performed to their design and if not, would it be economically feasible to bring them up to design levels.

This report will provide the above listed data, along with necessary supporting data, in the form of text, tables and charts. Chapter II presents basic descriptive hydrology of the study area. Included in this description are: topography, soils, vegetation, climate, the Sacramento River Flood Control System (SRFCS), and a discussion of general basin flood and flow characteristics. Chapter III looks at the hydrologic analysis of the study area for both the 1986 event and synthetic events. This chapter includes the development of volume-frequency curves for both the Sacramento and American Rivers and details the HEC-1 rainfall-runoff computer model. Chapter IV looks at the hydraulic analysis of the study area using the DWOPER (Dynamic Wave Operational Model) computer program. Chapter V discusses the development of the stage-frequency curves. Chapter VI discusses the Probable Maximum Flood (PMF) and sediment inflow amounts for Auburn Dam.

3. **COMPUTER PROGRAMS** - Due to many flow and stage complexities, it was necessary to use two computer programs to successfully model the study area. Basic rainfall induced runoff was computed using the HEC-1 Flood Hydrograph Package. This package was used where backwater effects are not a problem. In areas of major backwater influence, negative head differences (ie: upstream flow) and stage caused weir flow, the DWOPER (Dynamic Wave Operational Model) computer program was used. This program, developed by the Hydrologic Research Lab branch of the National Weather Service, is designed to be used in areas where backwater effects are troublesome for routing methods used in HEC-1 and HEC-2 (Water-Surface Profiles). DWOPER also affords the user the luxury of combining flow and stage hydrographs in order to test concurrencies and incorporate the influences which stage and flow have on each other, something that can be a problem when using HEC-2.

A. HEC-1 Model - The areas listed below were modeled with HEC-1.

RIVER	AREA
Sacramento River System	Above Fremont Weir
Feather River	Above Bear River
Natomas Cross Canal	Above Pleasant Grove Canal
American River	Above Folsom
Natomas East Main Drain	Arcade Creek
	Dry Creek
	Local above Dry Creek (Elverta drainage)

B. DWOPER MODEL - The reaches listed below were modeled with DWOPER.

RIVER	REACH
Sacramento River	Tisdale Weir to Courtland
Sutter Bypass	Tisdale Weir to Fremont Weir
Yolo Bypass	Fremont Weir to Lisbon
Feather River	Bear River to Sacramento River
Natomas Cross Canal	Pleasant Grove Canal to Sacramento River
American River	Nimbus to Sacramento River
Natomas East Main Drain	Sankey Road to American River

CHAPTER II - DESCRIPTIVE HYDROLOGY

1. BASIN DESCRIPTION -

A. GENERAL - The Sacramento River basin at the I-Street bridge drains approximately 23,500 sq mi. The General Map, Chart 1, shows the central portion of the Sacramento River Basin. The basin extends from near the Oregon border on the north, the peaks of the Sierras on the east, and the Coast Ranges on the west. Some of the main contributing rivers and creeks to the Sacramento River are the Feather and American Rivers and Cottonwood Creek. Flows on the American are controlled by Folsom Dam. Flows on the Feather are partially controlled by Oroville Dam. Some uncontrolled flows enter the Feather River below Oroville Dam. Cottonwood Creek is uncontrolled. Other uncontrolled flows enter the Sacramento River as it flows in a southerly direction from Shasta Dam to Sacramento.

B. TOPOGRAPHY - Topography of the basin varies from flat valley areas and low rolling foothills, to steep mountainous terrain. Elevations in the Sacramento Basin below Shasta and above Red Bluff range from about 280 feet to near 8,000 feet in the upper reaches of Cottonwood Creek. In this reach, the main stem of the Sacramento River has a slope of about 5 ft/mi. In the reach from Red Bluff to Ord Ferry, elevations range from less than 100 feet at Ord Ferry to near 10,000 feet at the top of Mt. Lassen. Approximately 50% of the area is below 1,000 feet. The average slope of the Sacramento River is about 1 ft/mi. Below Ord Ferry and above Fremont Weir, elevations range from below 100 feet to near 3,000 feet in the Coast Ranges. The slope of the Sacramento River is less than 1 ft/mi. Below Fremont weir, the Sacramento River is fed by the Feather and American Rivers. The elevations in the Feather and American Rivers range from about 100 feet to near 10,000 feet in the upper reaches of the Sierra Nevadas.

C. SOILS - Soil cover in the Sacramento River Basin is moderately deep with classifications varying from sands, silts and clays in the valley areas to porous volcanic area in the northern end of the basin. In the American and Feather River Basins, the soils range from granitic rock in the upper elevations to alluvial deposits in the valley areas.

D. VEGETATION - Vegetation in the higher elevations of the study area is dominated by coniferous forest. The foothills and valley areas are dominated by an oak-brush-grassland environment. Many valley areas in the Sacramento River Valley are cultivated.

2. CLIMATE - The climate in the Sacramento River Basin is temperate and varies according to elevation. In the valley and foothill areas the summers are hot and dry and the winters cool and moist. At the higher elevations the summers are warm and slightly moist and the winters are cold and wet.

A. **TEMPERATURES** - Average annual temperatures in the Sacramento River Basin range from the middle 60's in the valley areas to the low 50's at the higher elevations. Temperatures range from nearly 120 degrees in the northern valley to below zero in the Sierra Nevadas. Average monthly temperatures for the National Weather Service's Downtown Sacramento location are shown on Table 1.

TABLE K-1
NATIONAL WEATHER SERIVCE - DOWNTOWN SACRAMENTO STATION
AVERAGE MONTHLY TEMPERATURES

MONTH	MAXIMUM °F	MINIMUM °F
January	53.9	40.2
February	60.6	43.7
March	65.4	45.2
April	71.9	48.2
May	79.7	52.8
June	87.1	57.3
July	93.1	60.0
August	91.5	59.6
September	87.6	58.1
October	78.0	52.6
November	64.1	45.3
December	54.6	40.4
Yearly	74.0	54.3

B. **PRECIPITATION** - Normal annual precipitation (NAP) varies widely throughout the basin, ranging from the low teens in valley areas to over 70 inches in some mountain areas. NAP maps can be found on Charts 2, 18, 21, and 64. Normal monthly precipitation totals for Sacramento (#11 on Chart 18), Red Bluff (#8 on Chart 2), and Georgetown Ranger Station(#58 on Chart 64) are shown on Table 2.

TABLE K-2
AVERAGE MONTHLY PRECIPITATION (inches)

MONTH	SACRAMENTO	RED BLUFF	GEORGETOWN RS
January	4.18	4.50	11.36
February	2.94	3.31	7.72
March	2.18	2.39	7.06
April	1.44	1.51	4.79
May	0.35	0.77	1.77
June	0.13	0.43	0.57
July	0.05	0.06	0.23
August	0.09	0.10	0.28
September	0.30	0.46	0.68
October	0.90	1.16	2.88
November	2.31	3.10	6.24
December	3.00	3.59	9.35
Annual	17.87	21.38	52.93

3. **EXISTING WATER RESOURCES PROJECTS** - There are many existing projects in the study area. A description of many of these projects can be found in the report entitled "Sacramento Metropolitan Area, California, Reconnaissance Report", Dated February 1989.

4. **SACRAMENTO RIVER FLOOD CONTROL SYSTEM** - The Sacramento River Flood Control Project, shown on Chart 3, was authorized by the Flood Control Act of 1917. The project consisted of putting levees along the major rivers, to handle the small flood flows, and constructing a levee bypass system to handle large floods.

   The flood control project was designed on the basis that 600,000 cfs passing Rio Vista constitutes a very rare flow and the upstream flows that contribute to the 600,000 cfs were also rare events. The project's levees, weirs and bypasses are shown below.

LEVEED REACHES

RIVER	REACH
Sacramento	Ord Ferry to San Francisco Bay
Feather	City of Oroville to Sacramento River
American	Mayhew Drain to Sacramento River

WEIRS	BYPASSES
Moulton	Sutter
Colusa	Yolo
Tisdale	Sacramento
Fremont	
Sacramento	

Also included were numerous levees to control backwater from the River and Bypass system.

Storms from the Pacific track through the Sacramento River Basin, of which the Feather and American Rivers are tributaries, in many different ways. The System intercepts the runoff and moves it, without being life threatening, to the San Francisco Bay. Flood waters coming down the Sacramento River flow over the Tisdale Weir first, the Colusa Weir second, Fremont Weir third, Moulton Weir fourth, and the Sacramento Weir last. Tisdale, Colusa, and Moulton Weirs overflows enter into the Sutter Bypass, which dumps its waters into the Yolo Bypass, over Fremont Weir, and the Sacramento River at the Feather River mouth. Fremont Weir water goes into the Yolo Bypass, which empties back in to the Sacramento River near Rio Vista. The Sacramento Weir water flows through the Sacramento Bypass into the Yolo Bypass. The Feather River flood flows comingle with the Sutter Bypass flood waters upstream of the Feather River mouth. American River flood flows enter into the Sacramento River and flow both downstream and upstream. Upstream flows enter the Yolo Bypass via the Sacramento Weir and Sacramento Bypass. The levee crown elevations were originally established using water surface profiles that complemented the design flows (that made up the 600,000 cfs) and an estimated freeboard to handle the wind waves. The level of protection that the levees provide is an unknown. Because of the 1986 flood, studies are being conducted to determine the level of protection that all the levees in this system provide.

Since the original project was authorized, many reservoir projects have been constructed to control the runoff into the Sacramento River system. Some of these major projects are shown below.

RESERVOIR	YEAR BUILT	FLOOD CONTROL SPACE (ac-ft)	STREAM
Shasta	1945	1,300,000	Sacramento
Oroville	1967	750,000	Feather
Folsom	1956	400,000	American
New Bullards Bar	1966	170,000	Yuba
Black Butte	1963	137,000	Stony

Historical floods have tested this system many times, but none stressed the system like the February 1986 flood. In many areas the design flows were exceeded.

The Sacramento flood control system stages are sensitive to all flows and levee failures within the system. The stages in the area of Fremont Weir are dependent upon how the flows occur in time and magnitude in the Sacramento, Feather, and American Rivers. In addition, historically, during major runoff events levee failures have helped to reduce downstream stages. Thus, if upstream levees are prevented from failing, there is a greater potential for higher stages than have occurred historically. During the February 1986 flood event, the lower part of the system, from the mouth of the Feather River to below Rio Vista, experienced flows which surpassed previous records. Table 3 lists a comparison of 1986 flows and stages to design flows and stages.

TABLE K-3

COMPARISON OF DESIGN FLOWS AND STAGES
AND
PEAK FLOWS AND STAGES DURING FEBRUARY 1986 FLOOD EVENT

Location	Chart 1 Location Number	Design Flow (cfs)	February 1986 Peak Flow (cfs)	Design Stage (msl)	February 1986 Peak Stage (msl)
Sacramento River at Verona	34	107,000	92,900	38.2	39.11
Sacramento River Fremont Weir Spill	39	343,000	341,000	37.8	38.54
Yolo Bypass near Woodland	40	377,000	374,000	31.3	31.46
Yolo Bypass near Lisbon	49	490,000	495,000 to 509,000 (estimated)	23.2	24.88
Sacramento River Sacramento Weir Spill	42	112,000	127,680	31.5	30.56
Sacramento River at I-Street	45	110,000	115,000	31.1	30.58
Sacramento River at Freeport	48	110,000	117,000	25.4	25.11
American River at H-Street	44	115,000 152,000	134,000	40.0 42.0	40.4

5. GENERAL BASIN FLOOD CHARACTERISTICS - Major flood producing storms over Northern and Central California are generally associated with storm systems which originate in the Gulf of Alaska and develop a warm, moist air inflow from about the latitude of Hawaii. This combination results in moist unstable air. As the air mass encounters the north-south Coast Range it is orographically lifted (lifting caused by a mountain range). This lifting causes a cooling of the air mass. As the air cools, its ability to hold water is reduced. Therefore, the water which cannot be retained aloft is released as rain or snow. This is the basic recipe that caused the February 1986 flood event.

   Adding to the natural storm and flood complexities are the reservoir releases within the flood control system. Even though these reservoirs control rare events, their releases can also result in large flows. Since Mother Nature's wrath cannot be 100% predicted, times will come when large releases are necessary to make room for unforeseen inflows. In 1986, large flood flows in the American and Feather Rivers were a result of releases from Folsom and Oroville Dams, which were smaller than the inflows to these reservoirs.

6. FLOW CHARACTERISTICS - The flood control system exhibits many complex flow characteristics. Included in these complexities are weir diversions, upstream flows and mutual backwater effects at river junctions. Three of the more interesting locations are mentioned below.

   A. **Feather River** - During periods when the Feather River is experiencing high flows, as in 1986, the peak stage recorded at the Sacramento River at Verona gaging station (39.11 NGVD in 1986) is higher than the peak stage recorded at the Sacramento River at Fremont Weir West End station (38.56 NGVD in 1986) even though the West End station is approximately 5 miles upstream of Verona. Surface flows have been observed moving in the upstream direction, during several large floods.

   B. **American River** - During periods when the American River is experiencing high flows, as in 1986, the diversion effect of the Sacramento Weir will cause American River waters to merge with the Sacramento River waters and flow upstream in the Sacramento River, exiting over the Sacramento Weir into the Yolo Bypass.

   C. **Natomas East Main Drainage Canal** - The Natomas East Main Drainage Canal (NEMDC) is greatly influenced by the single or combined backwater effects of the Sacramento and American Rivers. The NEMDC then, in turn, affects the water-surface and flow in Dry Creek and Arcade Creek tributaries.

CHAPTER III - HYDROLOGIC ANALYSIS

1. **GENERAL** - This chapter will discuss the development of: (1) the flow-frequency curves and Standard Project Flood for the American River Basin, and (2) the volume-frequency curves at the confluence of the Sacramento and Feather Rivers (SFRC), and (3) the HEC-1 runoff models for the areas contributing flow to the Natomas Cross Canal, Dry Creek and Arcade Creek along with the Elverta drainage area.

   These analyses were used to develop the flow hydrographs used as input to DWOPER.

2. **AMERICAN RIVER** -

   A. AMERICAN RIVER FLOOD CONTROL PROJECT -

   1. **General** - The American River Flood Control Project, constructed by the Corps in 1958, consists of a levee along the north bank of the American River (See Chart 1). The levee extends from the eastern boundary of Cal Expo upstream to the Carmichael Bluffs, a distance of approximately 8 miles. The project levees are designed for 115,000 cfs with a minimum of 5 feet of freeboard.

      As part of the Sacramento River Flood Control Project, the south bank levee was upgraded in 1948 to Corps standards. The levee extends from the Mayhew Drain at Mayhew Road downstream to the east bank of the Sacramento River. The north bank levee from a point near the eastern boundary of Cal Expo to the Sacramento River was constructed and/or upgraded to Corps standards in 1955. These upgrades were done in order to meet the 3 foot freeboard at 152,000 cfs and 5 foot freeboard at 115,000 cfs requirements. Also included in the upgrade were pumping facilities and gravity drains to facilitate interior drainage.

   2. **Folsom Dam** - Folsom Dam and reservoir is a multiple-purpose project constructed by the Corps and operated by the Bureau of Reclamation (USBR) as part of the Central Valley Project (CVP). Folsom Dam regulates runoff from about 1,860 square miles. Folsom has a normal full pool storage capacity of 1,010,000 acre-feet (ac-ft) with a seasonally operated flood control space of 400,000 ac-ft.

   3. **Nimbus Dam** - Nimbus Dam and its accompanying Lake Natoma are located about 6 miles downstream from Folsom Dam. Nimbus Dam is a power afterbay to Folsom and a diversion dam. It is operated by the USBR as part of the CVP. The reservoir has a capacity of 8,760 ac-ft.

   B. FEBRUARY 1986 FLOOD - In February 1986, large flood flows in the American River Basin caused record inflow volumes to Folsom Reservoir. A maximum 6-day inflow volume of 1,140,000 ac-ft exceeded the 6-day

Reservoir Design Flood of 978,000 ac-ft. Because of fairly dry conditions earlier in the water year, about 200,000 ac-ft of storage space was available in upstream reservoirs. If the flood volume which had been stored in the upstream reservoirs had been added to Folsom's inflow, the 1986 flood would have resulted in 5- and 6-day volumes greater than the Standard Project Flood volumes computed in 1961. Releases from Folsom exceeded the objective outflow of about 115,000 cfs for about 2 days, and it was necessary to release flows of 130,000 for approximately 24 hours in order to keep Folsom from being severely encroached. During the flood, significant levee erosion occurred along the American River at several locations, and the design 5-foot freeboard was encroached along the north levee in the vicinity of Howe Avenue Bridge. In addition, encroachment of nearly 2 feet into the design freeboard of 3 feet occurred along the NEMDC, in part due to high stages on the American River.

Two reconnaissance reports, "Sacramento Metropolitan Area, California", dated February 1989 and "American River Watershed Investigation, California", dated January 1988, detail flooding problems and performance of levees in the study area during the February 1986 flood.

C. **FLOOD PROTECTION** - The degree of flood protection along the lower American River is estimated based on the expected frequency of flows exceeding the Reservoir Design Flood (400,000 ac-ft of flood control storage with a maximum outflow of 115,000 cfs). The Reservoir Design Flood for Folsom, developed in 1945, is an estimate of the flood that would have resulted from the most critical storm that had been recorded in the climatic region. A study of the precipitation during storms of record in the region indicated that the December 1937 storm was the most critical. The Reservoir Design Flood has a peak flow of 340,000 cfs and a volume of 978,000 ac-ft of runoff in 6 days.

At the time of the construction of Folsom Dam, protection against the Reservoir Design Flood was considered very high. However, primarily due to additional years of record, and the flood of 1986, the Reservoir Design Flood is now estimated to occur much more frequently. Since the completion of Folsom Dam, three rain floods have exceeded the volume of the Reservoir Design Flood (December 1955, December 1964, and February 1986).

D. **FLOW-FREQUENCY ANALYSIS** -

1. **Unregulated Conditions** - In 1961, a statistical analysis was done to estimate the likely frequency of occurrence for various flows in the American River at the Fair Oaks gage downstream from Folsom Dam. This analysis indicated that Folsom could control all flows up to the 120-year flood. However, because of the 1986 flood and since 5 of the 10 largest flows in the basin for 82 years have occurred since

1961, and 7 of 10 largest events have occurred since 1951, a new flow-frequency analysis was conducted. The first step in this re-analysis was to update the unregulated rainflood volume-frequency relationships at the Fair Oaks gage. These relationships reflect the flow data collected for the period 1905 to 1954 and adjusted flow data from 1955 to 1986. The adjusted flow accounts for the effects of French Meadows, Hell Hole, Loon Lake, Union Valley, and Ice House Reservoirs. This adjustment is necessary to provide a consistent record for statistical analysis. Pertinent information about the lag times used to route flows into Folsom is shown in Table 4.

Updated rainflood volume-frequency curves are shown on Chart 4. They reflect 82 years of record (1905-1986) for unregulated conditions for the American River at the Fair Oaks gage, for 1-, 3-, 5-, 7-, 10-, 15-, and 30-day durations.

TABLE K-4

UPSTREAM RESERVOIR ROUTING INFORMATION

Reservoir	Drainage Area (sq-mi)	Distance to Folsom (river miles)	Average Velocities (ft/sec)	Lag Times (hours)
French Meadows	47	61	3.4	26
Hell Hole	114	68	3.4	29
Loon Lake[1]	30	75	3.6	31
Union Valley	84	57	2.7	31
Ice House	27	64	2.8	33

[1] Loon Lake drains only 8 square miles, but receives the diversions from drainage areas above Hell Hole Reservoir. Up to 1,200 cfs is diverted to Loon Lake. The remainder continues downstream to Hell Hole Reservoir.

2. **Existing (Regulated) Conditions** - A revised peak flow frequency curve was developed for the American River at Fair Oaks. Estimated effects of storage in the reservoirs upstream in the basin were included in the derivation of the curve. The 31 years of actual recorded flow data since construction of the dam were used to define the plotting positions of flows more frequent than about the 50-year exceedence interval. To help define the plotting positions of flows less frequent than the 50-year event, hypothetical flood hydrographs were developed and routed through Folsom. The routing assumed currently operating criteria, some of which has been updated from that used in the operation during the February 1986 flood. The resultant flow-frequency curve is shown on Chart 5.

The effects of the upstream reservoirs are shown on the 100-year hydrograph on Chart 6. The reduction in inflow to Folsom Lake due to storage in these reservoirs is evident in the rising limb of the

100-year hydrograph. A review of historical floods showed that about 47,000 ac-ft of effective upstream storage would be available during major floods up through the 100-year frequency. No reductions in inflow to Folsom were made for floods larger than the 100-year. It was assumed that preceeding storms would have been sufficient to fill the upstream storage space. Only about 14 percent of the American River Basin lies above the reservoirs in Table 4.

The following assumptions were used in the reservoir routings for Folsom:

A. At the beginning of each hypothetical flood, Folsom was assumed to have an initial encroachment of 80,000 ac-ft in the flood control space with a concurrent outflow of 20,000 cfs. The encroachment was based on historical averages and to account for uncertainties in realtime operation. The outflow of 20,000 cfs is the assumed flood control release.

B. Releases from Folsom Dam were limited by outlet and spillway capacities. Releases below the spillway crest were made through the outlet works. An additional 7,000 cfs was released through the powerhouse.

C. Releases were made in conformance with the Flood Control and Emergency Release Diagrams currently in use. The Emergency Release Diagram governs releases greater than the design channel capacity.

E. Standard Project Flood - The USBR requested that the SPF be re-evaluated as part of this study. For this study, the SPF was computed as a percentage of the Probable Maximum Flood (PMF). The SPF hydrograph is shown on Chart 7. A PMF was developed in 1980 (revised July 1983) for the American River Basin and is documented in the report entitled "American River Basin, California, Folsom Dam Spillway Adequacy Studies, Hydrology". The PMF represents a flood that may be expected from the most severe combination of hydrologic and meteorologic conditions. For this analysis, 60 percent of the PMF was used for the revised SPF, based on SPF/PMF ratios used for similar basins in the Sierras. Under unregulated conditions, the revised SPF plots at about a 350-year frequency for a 1-day flow, 250-year for a 3-day flow, and a 200-year for a 4-day duration. This flood is about 15 percent larger in peak and 34 percent larger in volume than the SPF developed in 1961.

F. Folsom Reservoir Outflow Summary - Table 5 summarizes Folsom Reservoir outflow flow-frequency relationships. It shows peak inflows and outflows for selected flood events. The table shows that

Folsom can control all events up to the 63-year flood to outflows of 115,000 cfs or less. It also indicates that above about the 200-year event, outflow will be approximately equal to inflow.

TABLE K-5

FOLSOM RESERVOIR OUTFLOW - FLOW FREQUENCY [1]

Flow-Frequency Return Period (yrs)	Peak Inflow (1000 cfs)	Peak Outflow (1000 cfs)
50	274	115
63	300	115
85	332	180
100	353	234
200	442	432
250 (SPF)	530	530
400	543	543
500	578	578

[1] Due to the failure of the upstream cofferdam, the February 1986 peak inflow was 333,000 cfs with a peak outflow of 134,000 cfs.

3. **SACRAMENTO RIVER** -

A. GENERAL - The Sacramento-Feather River confluence (SFRC) is the combination point of over 21,000 square miles of drainage. Below this point, flood flows are split between the Sacramento River, which continues past the junction with the Natomas Cross Canal, and the Yolo Bypass. This study required the development of the 100-, 200-, and 400-year flood hydrographs and stages at the SFRC point in the Sacramento River Flood Control system under present hydrologic conditions. The peak flows from these three floods will be used to determine stages for these frequencies in the Sacramento River and Yolo Bypass at selected locations from the Sacramento-Feather River Confluence (SFRC) downstream to Lisbon on the Yolo Bypass and to Courtland on the Sacramento River. The following paragraphs describe (1) the flood characteristics and basin; (2) basin model selection and use; (3) the methods used to determine the flow volume frequency curves for SFRC; and (4) the derivation of the 100-, 200-, and 400-year floods.

B. FLOOD CHARACTERISTICS AND LOWER SACRAMENTO RIVER BASIN DESCRIPTION - Flood flows in the upper Sacramento River Basin below Shasta Dam are generally confined to their channels and their immediate overbank areas. After passing near Red Bluff and the Iron Canyon Ridge, the Sacramento River flows onto a broad alluvial plain flanked by the Butte and Colusa basins. Most of the tributary flows do not enter the Sacramento River directly but instead flow for considerable distance downstream through the Butte and Colusa basins before reaching the Sacramento River. See

General Map, Chart 1. The Butte and Colusa basins have, in the past, received considerable overflow from the main river floods. The principal flood basins between Red Bluff and the SFRC are described in the following subparagraphs.

1. **Butte Basin** - Butte Basin is north of Sutter Buttes and south of the latitude of Ord Ferry. It has an area of 150 square miles and a detention-storage capacity of 700,000 acre feet at flood stages. It receives overflow water from Sacramento River over low banks near Ord Ferry (when the river is above 90,000 cfs); through the overflow weir at Moulton (when the river is above 60,000 cfs), and Colusa Weir (when the river is above 30,000 cfs); and has received overflow north of the Sutter Buttes from the Feather River prior to construction of levees along the west bank of Feather River. Butte Basin discharges pass through the Butte Slough outfall gates into the Sacramento River when the river is low, and into Sutter Bypass when the river is high.

2. **Sutter Basin** - Sutter Basin is south of Sutter Buttes. It has an area of 138 square miles and has a potential detention-storage capacity of 890,000 acre-feet when levee failures occur. Design capacity of the Sutter Bypass varies from 178,000 cfs below the Sutter Buttes to 216,000 cfs at its confluence with the Feather River.

3. **Colusa Trough** - Colusa Trough is on the west side of the Sacramento River, extending from south of Stony Creek to Cache Creek, and has a detention-storage capacity of 690,000 acre-feet. The eastern side of this basin has been partially reclaimed by levees and an interception ditch along the west side of these levees. The interception ditch discharges into Sacramento River through Knights Landing outfall gates when the river is low, or into the Yolo Bypass through Knights Landing Ridge Cut when the river is high. Flows in the Sacramento River at Ord Ferry would have to exceed 300,000 cfs before any water would spill into the Colusa Trough.

4. **Feather River Levees** - The levees along the Feather River and its tributaries from Oroville to Nicolaus protect about 530 square miles from flooding, with an estimated detention storage of over 600,000 acre-feet with levee failure. Design channel capacity on the Feather River varies from 210,000 cfs above the Yuba River to 320,000 cfs below the Bear River. The Yuba River has a channel capacity of 180,000 cfs when Feather River flows are low, and 120,000 cfs when Feather River flows are high.

The largest peak flows at the SFRC seem to be caused by storm centerings over the Feather River Basin. Since the 1930's, good flow records been available on a continuous basis for most of the drainage area above the

SFRC. The three largest storms during this period, February 1986, December 1964 and December 1955, were centered over the Feather River Basin.

C. **BASIN MODEL** - As previously discussed, the Sacramento River System below the latitude of Ord Ferry is very complex. Many flood control and channel projects have been completed in the basin during the last 60 years. The historic flow and stage data at the Sacramento-Feather River confluence reflect a variety of upstream regulation and levee improvements. To correctly analyze these regulations and improvements, it was necessary to adjust the historic flow record of the Sacramento River and its tributaries to present hydrologic conditions. This was to be accomplished using a routing model to route the larger historical flood flows through the reservoirs and the flood control system. Two routing models were tested: the NOAA River Forecast Center's RWT 70 model, and the HEC-1 model used for the Cottonwood GDM Report.

RWT 70 is a real time model used by the California Department of Water Resources and the Federal River Forecast Center to route flows through the Sacramento River Basin. The operation of this model was compared to the HEC-1 model of the flood system and was found to be more difficult to operate than the HEC-1. It is also inflexible when it comes to modeling possible levee failure scenarios.

The HEC-1 model was chosen for its flexibility and its ability to use different routing and diversion methods.

To simulate the movement of the flood flows through the flood control system, an HEC-1 model was set up to route the Sacramento River at Ord Ferry flood hydrograph into the upper Butte Basin, where it was combined with flows from Butte Creek and local areas. The combined flows were then routed, using a simulated reservoir routing, through the Sutter Bypass to Highway 162 and downstream to the Feather River. The Feather River hydrograph above the Yuba River was combined with the Yuba River hydrograph to produce the combined flow on the Feather River at Shanghai Bend. The flow at Shanghai Bend was combined with the flow from the Bear River and then routed to the Sutter Bypass and combined with the Sutter Bypass flows. This flow was routed to the Fremont Weir where it was combined with the Sacramento River before flowing over Fremont Weir. The routing diagram is shown on Chart 8.

The HEC-1 model was calibrated using the 1983 and 1986 floods. Reproductions are shown on Charts 9 and 10. These floods were used because the upstream basins reflected all of today's conditions with all present flood control features in operation.

All input hydrographs reflected present conditions, and were input into the model at:

A. Sacramento River at Ord Ferry

B. Butte Creek at Chico

C. Butte Basin Local

D. Feather River above the Yuba River (200- and 400-year floods only)

E. Yuba River above the mouth (200- and 400-year floods only)

F. Bear River at Wheatland

Output hydrographs were computed for the following locations:

A. Sacramento River-Feather River confluence

B. Sacramento River at Verona

C. Yolo Bypass below the Fremont Weir

D. VOLUME-FREQUENCY CURVES - The development of the 100-, 200-, and 400-year floods and stages required an understanding of what causes the high stages at the SFRC. A review of several large floods revealed that a large number of flow combinations from the Sutter Bypass, Sacramento River and Feather River can occur. Therefore, a volume-frequency relationship was developed at the SFRC, which reflects the many concurrent flows that have occurred historically. The 100-, 200-, and 400-year floods were calculated using this relationship.

Volume-frequency curves were developed for durations of 1-, 3-, 5-, 7-, 10-, and 15 days. These curves reflect today's conditions with all present flood control features in operation. They also reflect no levee failures until design flows, as computed in 1920's, have been exceeded. Design capacities of upstream project levees are shown in Table 6. Upstream flood control reservoirs are listed in Table 7. In order to compute the volume-frequency curves, the data must be as homogeneous, continuous and reliable as possible.

TABLE K-6

DESIGN FLOWS ABOVE THE
SACRAMENTO-FEATHER RIVER CONFLUENCE

Location	Design Flows (in cfs)
Sacramento River Below	
Ord Ferry	90,000
Butte City	160,000
Moulton Weir	135,000
Colusa Weir	66,000
Tisdale Weir	30,000
Sutter Bypass	
Sutter Buttes to Tisdale Bypass	155,000
Tisdale Bypass to Feather River	180,000
Feather River to Fremont Weir	380,000
Feather River	
Above Yuba River	210,000
Below Yuba River	300,000
Below Bear River	320,000
Yuba River	120,000
Sacramento-Feather River Confluence	410,000

TABLE F-7

UPSTREAM FLOOD CONTROL RESERVOIRS

Storage Facility	Year Start Storage	Total Capacity 1000 AF	Flood Control Space 1000 AF	Controlled Max. Release 1000 cfs	Downstream Protection
Shasta Res.	1943	4,552	1,300	79	100 year
Black Butte Res.	1963	160	137	15	60 year
Oroville Res.	1964	3,538	750	150	150 year
New Bullards Bar	1969	960	170	50	100 year

In order to have a homogeneous data set for developing the frequency curves, all flow data must reflect present physical conditions. Even though many floods have occurred, it is extremely difficult to reconstruct all the flood hydrographs for the purposes of routing them through the present system.

The drainage area above the SFRC is very large, and many different rain flood centerings are possible. Using the largest floods that occurred during a continuous record, provides a good representation of many different centerings. Floods for the period 1929-1988 were selected because continuous records were not available for floods prior to 1929.

The eleven largest floods from 1929-1988 (59 years) were chosen to determine the volume frequency curve from the 6-year to the 100-year event. Historic hydrographs were developed to reflect routing effects of upstream flood control reservoirs. These hydrographs were routed, using the HEC-1 model, to the Sacramento-Feather River confluence to obtain peak and volume-duration flows at this point. Peaks and volumes for these floods are shown in Table 8.

TABLE K-8

SACRAMENTO-FEATHER RIVER CONFLUENCE HISTORICAL FLOODS OF RECORD ADJUSTED TO PRESENT CONDITIONS

Flow in 1000 Mean Day-cfs

DATE	PEAK	1-DAY	3-DAY	5-DAY	7-DAY	10-DAY	15-DAY
Dec 1937	304.4	297.1	261.6	210.4	176.6	141.8	108.0
Feb 1940	322.4	308.9	286.1	252.6	220.2	190.6	161.4
Mar 1940	239.5	237.8	224.5	194.8	173.9	155.8	129.9
Jan 1942	260.5	257.6	248.8	226.3	207.1	182.0	172.7
Dec 1955	368.6	366.5	344.3	313.2	281.2	243.7	195.5
Feb 1958	254.0	251.0	241.8	220.6	208.6	199.5	164.4
Dec 1964	379.4	368.4	351.2	315.6	281.9	240.5	183.0
Jan 1970	308.4	304.4	291.9	276.2	265.3	252.5	229.7
Jan 1974	205.9	205.1	202.2	195.1	185.3	171.2	150.2
Feb 1983	281.7	278.6	264.1	246.4	229.3	211.4	205.6
Feb 1986	429.8	414.0	387.9	355.0	319.1	281.9	236.4

Since these are the 11 largest floods recorded in a continuous record of 59 years, the peaks and duration flow from these events were assigned mean plotting positions for that period and then plotted on log probability paper. A best fit linear curve was then calculated for each duration using Leo R. Beard's method for analytical frequency computation, omitting events more frequent than the 6-year event. The method is explained in "Statistical Methods in Hydrology," published by the U.S. Army Corps of Engineers, Sacramento District in 1962. The computed statistics and the flow-duration curves are shown on Chart 11. Releases from the major upstream reservoirs are controlled for storm centerings somewhat rarer than a hundred-year event (see Table 7, pg 19). At some point between the 100-year and 200-year events, these reservoirs can no longer store flood runoff and must increase releases. In order to develop the upper end of the frequency curves, the 200- and 400-year hypothetical floods were developed and routed. The hydrographs that were routed through the reservoirs and combined in the system were computed from full natural reservoir inflow duration-frequency curves. Centerings over the Feather - Yuba River basins were used to develop these larger floods at the SFRC. A detailed explanation on the development of the 400-year and 200-year flow-duration curves is given in paragraphs F and G.

For purposes of determining the amount of flow that will likely reach the SFRC the Feather and Yuba River levees upstream of the mouth of the Yuba River are allowed to fail when flows exceeded design capacity. The Feather River design flow above the Yuba River is 210,000 cfs. The Yuba River design flow is 120,000 cfs. However, in 1964, the Yuba River passed 180,000 cfs without encroaching into the freeboard. Flows greater than 120,000 cfs in the Yuba River are possible when flows in the Feather River are 120,000 cfs or less. The levee failures on the Feather and Yuba River were implemented according to the approved levee failure scenarios presented in the 1977 Marysville GDM; that is, for this study, the Yuba River levees failed when flows exceeded 120,000 cfs (concurrent Feather River flows were high) and the Feather River levees failed when flows exceeded 210,000 cfs. After the levee failure on the Yuba River, Yuba River flows downstream of the failure consisted of the remaining in-channel flows of 10,000 cfs plus 50% of the flows above 10,000 cfs. These flows were then added to flows of the Feather River at Shanghai Bend for the total flow of the Feather River at Shanghai Bend. An example of this is if the Yuba River had a flow of 170,000 cfs, 10,000 cfs would remain in channel, 50% of the remaining 160,000, cfs or 80,000, cfs would be added to the 10,000 cfs for a total flow of 90,000 cfs (eg. 10,000 cfs + .5*160,000 cfs = 90,000 cfs) that continued downstream to Shanghai Bend. This flow would then be added to the flows from the Feather River at Shanghai Bend. The same procedure was used for failures on the Feather River. After levee failures on the Feather River, Feather River flows consisted of in-channel flows of 50,000 cfs plus 50 percent of the flows above 50,000 cfs. These flows were combined with flows from the Yuba River at Shanghai Bend.

E. **100-YEAR FLOOD** - The 100-year flood was computed at the SFRC from the volume-frequency curves. Volume-mass curves were drawn for the 50- and 100-year flood events, along with the 1955, -64, -83, -86 events. These curves reflect the 1- through 15-day volumes. The 50- and 100-year mass curves were derived from the volume-frequency curves on Chart 11. The mass curve for the 100-year event was similar in shape to that for the

1986 flood. Therefore, for this study, the 100-year hydrographs were patterned after the 1986 flood hydrographs. The 100-year peaks and volumes were obtained by increasing the 1986 flows to match the 100-year volume-duration data. The mass curves are shown on Chart 12. The 100-year hydrograph at SFRC is shown on Chart 13.

F. 400-YEAR FLOOD - There are two ways that a flood of the magnitude of a 400-year event could occur at the Sacramento-Feather River confluence (SFRC). The first is with a specific storm centered over the Sacramento River above Ord Ferry with a concurrent storm over the Feather River basin. Under this scenario, it is necessary for Shasta and Black Butte Reservoirs to release more than their objective flow (lose control). Very large flows would be experienced at Ord Ferry. However, peak and volume would be greatly reduced by the storage in the Colusa Trough and Butte Basin above the Sutter Buttes, and by levee failures in the Sutter Bypass above the Sacramento-Feather River confluence.

The second is with a specific storm centered over the upper Feather River basin with a concurrent storm over the Sacramento River Basin above Ord Ferry. Under this scenario, Shasta would not lose control but Black Butte, Oroville, and New Bullards Bar reservoirs would. Larger peaks would occur at the confluence because of the larger channel capacities and less overbank storage in the Feather River system. Historically, the largest flows have occurred at the SFRC when storm events are centered over the Feather River basin (as in 1955, 1964, and 1986). The largest flood flows at the mouth of the Feather River, for flood events greater than the 200-year event, would occur with centerings over the Feather River above the Yuba River.

Due to the complexity of trying to determine the synthetic storm centerings over the Feather and Sacramento Rivers, the 200-year and 400-year flood hydrographs at the SFRC were not computed using rainfall-runoff computations. The method used is described in the following paragraphs.

For this study, the 400-year event at the SFRC is based on an event having the greatest contribution from the Feather River. The 400-year, 15-day hydrograph for the Feather River above the Yuba River, and the Yuba River concurrent hydrograph, were patterened after the Standard Project Flood developed for the Feather and Yuba Rivers for the March 1977 General Design Memorandum Phase I Plan Formulation Preliminary Report. All local Feather-Yuba flows were based on the 1986 event. Concurrent flow hydrographs at Ord Ferry (including controlled Shasta releases) for the 400-year event were developed using the 1986 event as a model. This was accomplished by dividing the 1986 maximum 10-day flow volume at Ord Ferry, by the 1986 10-day unregulated flow volume at Shanghai Bend. This is the ratio of the contributing local 10-day volume at Ord Ferry, to the total unregulated 10-day volume on the

Feather River below the Yuba River (at Shanghai Bend) for the 1986 flood event. This ratio was then applied to the 400-year 10-day unregulated volume at Shanghai Bend, to find the corresponding 10-day volume at Ord Ferry. As a result, the 1986 flows at Ord Ferry were increased by 54%. This made the concurrent flood on the Sacramento River at Ord Ferry a 20-year event. The peak flow for Ord Ferry plots at approximately a 20-year event. All local flows below Ord Ferry on the Sacramento River and below Shanghai Bend on the Feather River for the 400-year event were taken to be approximately the same as the 1986 local flows.

For the 400-year event, peak flows of 320,000 cfs occurred on the Feather River above Yuba River, and 257,000 cfs on the Yuba River at the mouth. For this study it was assumed these flows exceeded design capacities and caused failures on the Feather and Yuba rivers above their junction at Marysville. The Yuba River flows exceeded design capacity before the Feather River so the Yuba River levees failed first (concurrent flows in the Feather River were high). A short time later the Feather River levees above Marysville failed when its flows exceeded design capacity. After the levee failure on the Yuba River, Yuba River flows consisted of the remaining in-channel flows of 10,000 cfs plus 50% of the flows above 10,000 cfs. Flows from the Feather and Yuba Rivers were combined and routed to Shanghai Bend. The combined Shanghai Bend flows peaked at 330,000 cfs. The design capacity 300,000 was exceeded for only two hours. Because the peak was so sharp and flows above design capacity so brief the levees at or below Shanghai Bend were not failed. These flows at Shanghai Bend were then routed ináchannel to Nicolaus and combined with the Bear River flows. These flows were again routed to the Sacramento River and combined with Sacramento River flows at the Sacramento-Feather River confluence. All flows from the Sacramento River and Sutter Bypass remained within their respective design capacities. The total flow at the confluence has a peak of 507,000 cfs and a one-day volume of 503,000 cfs which exceeded its capacity of 410,000 cfs. The 400-year flood hydrograph is plotted on Chart 14 and the volume-duration curves are shown on Chart 11.

These volume-duration curves reflect in-channel flows above the SFRC. Flood volumes at the latitude of the SFRC which include water from upstream levee failures would probably be higher for events greater than the 100-year and for durations longer than one-day. All out of bank and overland flows due to levee failures continue downstream, paralleling their respective waterways and eventually join the Sacramento or Feather River or are stored behind downstream levees. These flows, moving at lower velocities than the main channel flows, will take weeks or even months to reenter their respective channels. These upstream levee failures will cause extensive interior flooding and may require pumping to remove the water from behind downstream levees.

G. **200-YEAR FLOOD** - The 200-year flood at the SFRC was modeled after the 400-year discussed above. These flows were routed through Oroville

Reservoir on the Feather River and New Bullards Bar Reservoir on the Yuba River and combined at Shanghai Bend. All other concurrent flow hydrographs for the Sacramento River and Feather River below Shanghai Bend were the same as were used in the 400-year routing.

During the 200-year flood, Shasta Reservoir did not lose control, but Black Butte, Oroville and New Bullards Bar did. Flows in the Feather River above the Yuba River peaked at 173,000 cfs, 23,000 cfs greater than the objective operation of Oroville Reservoir but lower than the 210,000 cfs channel capacity. Peak flows in the Yuba River reached 192,000 cfs. The left bank levees on the Yuba River failed when flows exceeded 120,000 cfs. After the levee failure on the Yuba River, Yuba River flows consisted of the remaining in-channel flows of 10,000 cfs plus 50% of the flows above 10,000 cfs. These flows were then added to flows of the Feather River at Shanghai Bend for the total flow of the Feather River at Shanghai Bend. The 200-year combined Shanghai Bend flows peaked at 300,000 cfs but had a mean bi-hourly flow of 271,000 cfs. These flows, which are within the design capacities of the Feather River channel, were routed to Nicolaus, combined with the Bear River flows, routed to the Fremont Weir and combined with the Sacramento River and Sutter Bypass flows. The flow at the SFRC peaks at 484,000 cfs with a one-day volume of 475,000 cfs. The peak exceeds the SFRC's capacity of 410,000 cfs. The 200-year flow hydrograph is shown on Chart 15.

H. **NO FAILURE CONDITIONS** - For the 200-year flood, a cursory estimate showed that the flow at the SFRC would increase by about 70,000 cfs if no levee failures occurred. This increase in flow would result in an increase in stage at Verona on the Sacramento River (location 34 on Chart 1) of approximately 0.7 feet. The stage difference lessens going downstream on the Sacramento River from Verona. In the Yolo Bypass, increases in stages range from 0.7 feet just downstream of Fremont Weir to 0.2 feet at Lisbon (location 49 on Chart 1). These stages are based on the assumption that both Sacramento Weir and Fremont Weir can handle the increase in flow.

The 400-year flows in the Feather and Yuba Rivers and the concurrent flows in the Sacramento River-Sutter Bypass System exceed the design flows. Even if levees do not fail by being encroached they will be overtopped and fail. Detailed studies are necessary to determine where these overtoppings would occur, where the water would go after overtopping, and how much volume would reach the SFRC.

The existing Sacramento River Flood Control System is very sensitive to any improvements made to it. Increasing upstream levee heights to provide higher levels of flood protection will impact on downstream levees. It is important to look at overall effects when considering upstream levee improvements.

4. **SACRAMENTO AND AMERICAN RIVER TRIBUTARIES** -

A. GENERAL - The DWOPER model was calibrated using the February 14-22, 1986 and February 29-March 9, 1983 events. A necessary part of the DWOPER input was runoff hydrographs for Arcade Creek, Dry Creek, Elverta Drainage and the Natomas Cross Canal area. Therefore, HEC-1 models were developed for these areas. This chapter discusses the HEC-1 analysis of the 1986 and 1983 flood events along with the development of the synthetic hydrographs for the four areas. Subarea, topography and normal annual preciptation maps for these areas are shown on Charts 16 through 21.

B. HISTORICAL FLOODS -

(1) **General** - In the Arcade, Dry, Cross Canal and Elverta drainage basins, minimal runoff data exist for the 1986 and 1983 floods. Therefore, it was difficult to calibrate the HEC-1 model. For this reason, the 1986 and 1983 flood hydrographs were estimated based on estimated flows from high water marks and miscellaneous staff gage readings.

(2) **Rainfall** - Rainfall amounts for the 1986 and 1983 storms for each basin were determined by rainfall recorded at various stations throughout the area. The bulk of the 1986 rainfall fell during the period of February 18th-20th. Basin rainfall amounts ranged from 1.8 to 3.5 inches. The amounts for the entire period of the 1983 storm ranged from 3.2 to 6.4 inches. The rainfall was temporally distributed over the area based on actual recorded hourly amounts at the various stations.

(3) **Land Use** - Land use parameters for the Dry Creek basin were based on information in reference D. For the Arcade, Natomas Cross Canal, and Elverta areas, no up-to-date land use data were available. Therefore, land use parameters were estimated based on observations of the basin.

(4) **Loss Rates** - Loss rates and ratios of imperviousness for the Dry and Arcade Creek basins were based on the present land use conditions presented in references E and F, respectively. The impervious ratios for Arcade Creek were updated from the 1975 study to reflect current land use conditions. Loss rates and ratios of imperviousness for the Cross Canal and Elverta areas are based on general knowledge of the area and the loss rates and imperviousness factors used for the adjacent Dry Creek basin. Initial loss rates were in the .25 inch range and constant loss rates wavered around .10 inches per hour. Ratios of imperviousness ranged from 10% for open land to 90% for industrial areas.

(5) **Unit Hydrographs** - Unit hydrographs for Dry Creek were taken from the study described in reference D. Unit hydrographs for Arcade

Creek above Interstate 80 were taken from reference E. Unit hydrographs for the Cross Canal and Elverta drainage areas were computed using the same methods as were used for the adjacent Dry Creek basin. This methodology included the use of the modified Los Angeles District S-curve procedure, described in Technical Reference Bulletin No. 5-550-3, "Flood Prediction Techniques", dated February 1957. This procedure utilizes a non-dimensional summation graph (S-graph) in conjunction with basin characteristics and a general basin roughness factor, which relates lag time to basin runoff characteristics. The L.A. Valley S-graph, shown on Chart 22, was used for the Cross Canal and Elverta drainage areas. The general basin roughness factors for the areas were .115 and .120, respectively. Computational time intervals were 1-hour for the Cross Canal area and 15-minute for the Elverta area.

Below Watt Avenue, the subbasins were redefined based on drainage boundaries of the existing City of Sacramento pumping plants. Unit hydrographs for Arcade Creek below Interatate 80, were developed using the Clark method described in the Morrison Creek report, reference G. The HEC-1 users manual describes the Clark parameters T_c and R and how they are used to develop unit hydrographs. Chart 23 was developed for the Morrison Creek study. It shows the relationship between T_c+R and drainage area. Land uses in the lower Arcade Creek basin and Morrison Creek basin are very similar. Therefore, the relationships on Chart 23 were used to obtain T_c and R values for the lower Arcade Creek basin. Line 1 on Chart 23 represents urban areas. Line 5 represents agricultural areas subject to surface storage detention which slows runoff time. In general, the value of T_c+R decreases as urbanization increases. Table 9 lists T_c+R vs. drainage area line, drainage area, and T_c and R value for each subarea.

TABLE K-9
T_c and R VALUES - LOWER ARCADE CREEK

SUBAREA	Drainage Area (Sq. Miles)	LINE[1]	Tc	R
40	1.91	1	2.3	1.9
50	1.81	1+5	4.1	2.7
60	1.51	1	2.1	1.8
70	1.22	1	2.0	1.6
80	.78	1	1.6	1.4
90	1.08	1	1.9	1.5

1. Refers to numbered lines on Chart 23.

(6) **Routing Parameters** - Routing parameters for Dry Creek and Arcade Creek basins were taken from information in References E and F,

respectively. For the Cross Canal and Elverta areas, routing was done using HEC-1's normal depth routing routine. The program is given an average section of the routing reach along with the slope, distance, and approximate overbank and channel n-values. HEC-1 then computes a modified puls relationship for the reach.

(7) **Pumping Plants** - Two pumps discharge water into the Cross Canal. Their total capacity is approximately 970 cfs. Five pumps discharge water into the NEMDC. Their total capacity is approximately 1440 cfs.

(8) **Computed Flows** - Plots of the computed 1986 flood hydrographs are shown on Chart 24. These hydrographs will be used as input to DWOPER during the calibration procedure.

C. SYNTHETIC FLOODS -

(1) **Rainfall** - 100-year storm amounts were developed for the study area. An analysis of the recorded precipitation data in and around the study area indicated that storm waves of 24-hour duration were preeminent during the February 1986 storm. Therefore a 24-hour duration was used for the 100-year rainstorm. The 100-year 24-hour storm amount for each basin is based on an annual rainfall depth-duration frequency analysis by Mr. Jim Goodridge (reference A) for rainfall recording stations located at Navion (Dry Creek), Cresta Park (Arcade Creek) , Metro Airport (Elverta) and Roseville Filter Plant (Cross Canal). These recording station were selected due to their closeness to the respective basins. A comparison of 24-hour 100-year point rainfall amounts for various precipitation recording stations in the study area and NOAA ATLAS 2 (reference B) data is shown on Table 10. This Table shows that station data are generally higher. This difference is due to the fact that the station data reflects the high rainfall amounts recorded over the past few years.

TABLE K-10

100-YEAR 24-HOUR RAINFALL

RECORDING STATION NAME	100-YEAR RAINFALL (in.)	
	NOAA	STATION
NAVION	4.45	4.91
ROSEVILLE FILTERS	4.75	4.46
CRESTA	4.20	4.53
ORANGEVALE	4.30	4.45
RIO LINDA	4.10	4.30
SACRAMENTO CITY	4.10	4.46
SAC METRO. AIRPORT	3.60	3.68

a. **Arcade Creek** - Point rainfall amounts were adjusted by a factor of 0.960 for the 40 square mile Arcade Creek basin, based on criteria in reference B. Subarea 24-hour rainfall amounts were determined by multiplying total basin storm amount by the ratio of the subarea NAP to total area NAP.

b. **Dry Creek** - Point rainfall amounts were adjusted by a factor of 0.93 for the 143 square mile Dry Creek Basin, based on criteria in reference B. Subarea rainfall amounts were determined by using the subarea to total area ratio as described for Dry Creek.

c. **Elverta Drainage** - This area is small enough that no areal adjustment was made to the point precipitation. The 100-year amount at Sacramento Metro Airport was taken as the average 100-year rainfall for the entire Elverta drainage.

d. **Natomas Cross Canal** - For the Natomas Cross Canal drainage area, historical rainfall data is basically nonexistent in the upper part of the drainage basin. Rainfall data at the Cresta and Roseville Filter Plant should approximate the rainfall amounts in the lower part of the basin. However, these lower values may underestimate the average rainfall over the entire basin since the upper part of the basin should receive more rainfall based on its higher elevation. Therefore, the point value at Cresta was used to represent the 100-year storm for the basin and was not reduced areally since it may already be lower than the average basin 100-year 24-hour amount. The subarea rainfall amounts were determined by the NAP ratio method.

(2) **Rainfall Distributions** - The temporal distribution of the 100-year rainfall amount for Dry Creek is based on the 96-hour standard

project storm distribution for areas between 101 and 500 square miles, and for elevations less than 2000 feet (reference C). Reference D details the use of this pattern for Dry Creek. For Arcade, Elverta and Cross Canal a slightly different approach was taken and resulted in approximately the same magnitude of rainfall as used for Dry Creek. For these areas the 100-year, 1-, 2-, 3-, and 24-hour rainfall amounts were used . The 1-, 2-and 3-hour amounts were distributed around the middle of the 24-hour time period. The remainder of the rainfall (24-hour amount minus the 3-hour amount) was distributed over the remaining time periods. The resulting distribution formed a basic pyramid shape. Navion data were used for Arcade Creek. Roseville Filter data were used for the Cross Canal. Sacramento Metro Airport data were used for the Elverta area.

(3) **Synthetic Flood Results** - For this study it was assumed that the existing condition 100-year flood would be produced by the 100-year storm. Runoff for the existing condition 100-year flood was calculated using the HEC-1 computer package which used as input the 100-year rainfall described above, and the loss rates, unit hydrographs, land uses, routing parameters and pumping plant data used to reproduce the 1986 event. The 100-year existing condition flood hydrographs calculated for these areas are shown on Chart 25. These hydrographs were used as input to DWOPER when computing synthetic flood stages.

Some segments of the planning studies dictated a need for future runoff (year 2040). This runoff was computed exactly as described in the above paragraph. The only differences between existing and future conditions were in land use. The changes in land use were accounted for by raising the ratio of imperviousness in the affected areas. Future land use maps are shown on Charts 26 and 27.

CHAPTER IV - HYDRAULIC ANALYSIS

1. **GENERAL** - As mentioned in Chapter I, the study area maintains a complex hydraulic balance during large flood events. Among these complexities are backwater effects, negative head differences, and stage caused weir flow all of which differ over time. Therefore it was necessary to use a program capable of handling these complex situations as they change in time. The DWOPER program was chosen due to its capabilities and availability of in-house experience.

2. **DWOPER OVERVIEW** - The basic input for DWOPER (Dynamic Wave Operational Model) consists of input from GEDA (Geometric Elements for Cross Section Coordinates), inflow hydrographs at the upstream limit (boundary) of each river, lateral inflows at their corresponding locations in the system, and a stage hydrograph or rating curve at the downstream limit (boundary).

   The GEDA program is an interface between the channel geometric and roughness data, and DWOPER. It transforms the actual channel geometry and roughness data into a format compatible with DWOPER input formats. GEDA input consists of HEC-2 type cross sectional data, n-values for channel and overbank and a table of water-surface elevations which fall within the confines of the cross sections. GEDA computes the distances between cross sections along with the n-value and topwidth for each given water-surface elevation at each cross section.

   The output from GEDA is then used as input to DWOPER to describe the physical details of each river in the river system. Each river system may have one "main stem" river. Dynamic tributaries, those modeled with cross sections, may connect to the main stem river. However, a dynamic tributary may not connect to another dynamic tributary but a "lateral" inflow may enter the system at any point. Lateral inflows differ from dynamic tributaries in that they are simply input hydrographs. Flow out of a storm sewer is a good example of a lateral inflow. The Sacramento-American River junction is an example of a main stem-dynamic tributary junction, with the Sacramento being the main stem.

   Due to the DWOPER constraint of where dynamic tributaries can connect, it was necessary to break the study area into three separate DWOPER models. These will be called the Sacramento River, American River and Yolo Bypass models, respectively.

3. **MODEL CALIBRATION** - The flood events of 1986 and 1983 were chosen to calibrate the DWOPER model. The 1986 event was used to calibrate the model since it was the largest flood of record at many locations, a large amount of field observations exist, and a large network of stream gaging stations were in place during the flood to measure the flows and elevations at many locations. It was reasoned that if the model can reproduce the flood of record, then it would do well estimating less frequent events such as the 100-, 200-, and 400-year events. To assure that the model was not biased

towards the 1986 flood only, the 1983 event was used as a check. The next few paragraphs will detail the differences between the Sacramento River and American River models and how they were used to reproduce the 1986 flood.

A. SACRAMENTO RIVER MODEL - The Sacramento River model includes the Sacramento River from Tisdale Weir to Courtland, Sutter Bypass from Tisdale Weir to Fremont Weir, Feather River from the Bear River to the Sacramento River, Natomas Cross Canal from Pleasant Grove Canal to the Sacramento River and the American River from Nimbus to the Sacramento River (see Chart 1). The Sutter Bypass and the part of the Sacramento River below Fremont Weir are being used as the main stem river. Therefore, the Sacramento River above Fremont, Feather River, Natomas Cross Canal and American River are dynamic tributaries to the Sacramento River. Chart 28 shows a schematic of the main stem/dynamic tributary setup. This setup of the Sacramento River model is representative of the DWOPER model used for all flood events in this study.

(1) Boundary Conditions -

a. Main Stem River - The estimated flow hydrograph in the Sutter Bypass just downstream of Tisdale Weir was used as the upstream boundary hydrograph. This hydrograph was estimated by combining the recorded flows in the Butte Slough at Meridian (Chart 1, location 20) the Wadsworth Canal near Sutter (Chart 1, location 22) and the Tisdale Weir spill to the Sutter Bypass (Chart 1, location 12). The recorded stage hydrograph at the Sacramento River at Snodgrass Slough stage recording station (Chart 1, location 48) was used as the lower boundary.

b. Dynamic Tributaries - The recorded flow hydrograph at the Sacramento River at Wilkins Slough gaging station (Chart 1, location 15) was used as the upper boundary inflow to the Sacramento River. The estimated flow hydrograph in the Feather River below the Bear River was used as the upper boundary inflow to the Feather River. This hydrograph was computed based on the estimated flow in the Feather River at Shanghai Bend (Chart 1, location 29), Honcut Creek estimated local flow and Bear River at Wheatland (Chart 1, location 30) flows. The upper boundary inflow to the Cross Canal was computed using HEC-1 and recorded rainfall values. The flow recorded at the American River at Fair Oaks gaging station (this location is not shown on Chart 1 but is basically the outflow from Lake Nimbus shown on Chart 3) was used as the upper boundary flow for the American River. DWOPER uses the stage computed on the main river at the downstream end of the tributaries as the downstream boundary of the tributary. The upstream boundary hydrographs are shown on Chart 29.

(2) N-Values - N-values ranged from .018 to .040 for channels and .04 to .08 for overbanks depending on location. N-values are the main vehicle for adjusting the stage and flow values in DWOPER. At times, n-values may seem slightly high or low but are usually used in a short reach to help simulate a different type of flow such as reverse flow.

(3) **Sacramento Weir** - The Sacramento Weir was modeled using a weir crest elevation of 21.5 feet msl., a weir length of 1830 feet and a weir coefficient of 2.5. The Sacramento Weir presented some modeling problems because of the flashboards. The flashboards eliminate modeling the weir as a fixed weir crest structure. Also, certain criteria exist as to when the flashboards should be removed. These criteria are based on the elevation at the Sacramento River at I-Street gage. Once the elevation at I-Street reaches 27.5 feet msl then the boards are to be removed. Therefore, it was necessary to estimate the elevation at the Sacramento Weir when the elevation at I-Street reaches 27.5 feet msl. This elevation was estimated to be approximately 28.2 feet msl. In the eyes of DWOPER, removal of the flashboards began when the average elevation at the weir (upstream + downstream elevation/2) reached 28.5 msl. This removal took 6 hours and the final elevation after removal was 21.5 feet msl.

(4) **Fremont Weir** - The actual crest of the Fremont Weir is 30.5 feet msl. Over the years, much sediment has been deposited in front of the weir. In 1986 it was estimated that the ground on the upstream side of the weir averaged approximately 1.5 feet above the weir crest. Therefore, the effective elevation of the Fremont Weir was estimated to be 32.0 feet msl. A weir length of 7000 feet and a weir coefficient of 2.5 were used. Although the actual weir is longer than 7000 feet, its parallel length to the Sacramento River is close to 7000 feet .

(5) **Nelson Bend Training Structure** - The Nelson Bend training structure is located across the Feather floodplain where it intersects the Sutter Bypass. This structure keeps low flows in the main Feather River channel as it turns southward. The elevation of this structure is 36.5 feet msl. In the DWOPER model, once the Feather River waters exceed this elevation, water spills into the Sutter Bypass. The amount of water entering the Sutter Bypass depends on the elevation of the Feather River water and the elevation of the Sutter Bypass water. DWOPER accounts for weir submergence.

(6) **Lateral Inflows** - The pumping plants on the Natomas Cross Canal were treated as lateral inflows. The contribution of the NEMDC to the American River was treated as a lateral inflow in this model. The NEMDC is treated with more detail in the American River model.

(7) **Results** - The DWOPER reconstitutions of the 1986 and 1983 events are shown on Charts 30 and 31, respectively. Due to the quality of these reconstitutions, it was assumed that DWOPER would do an

acceptable job of computing elevations associated with large flood events in the area covered by the Sacramento River model.

B. **AMERICAN RIVER MODEL** - The American River model includes the American River from Nimbus to the Sacramento River and the Natomas East Main Drain (NEMDC) from Sankey Road (see Chart 1 for location) to the American River. The American River is the main stem river and the NEMDC is a dynamic tributary.

(1) **Boundary Conditions** - The Fair Oaks gage was used as the upper boundary inflow hydrograph to the American River. The lower boundary for the American River was computed by the Sacramento River model. The upper boundary inflow hydrograph to the NEMDC was computed using HEC-1. The American River hydrograph is shown on Chart 29.

(2) **N-Values** - N-values fell within the range used in the Sacramento River model.

(3) **Lateral Inflows** - Lateral inflows consist of Arcade Creek, Dry Creek, small tributaries in the Elverta drainage area and pumping plants. The Arcade, Dry and Elverta inflows were computed by HEC-1 using the data described in Chapter III. The pumping plant capacities were provided by the City of Sacramento. All pumps were assumed to pump at full capacity throughout the duration of the flood. Total pumping capacity is approximately 1440 cfs.

(4) **Overflow From Natomas Cross Canal** - Based on field observation, it was estimated that when the peak stages were occurring in the Natomas Cross Canal, a peak flow of approximately 500 cfs flowed south from the Natomas Cross Canal drainage, over Sankey Road, and into the NEMDC drainage. The overflow raises the water-surface in the NEMDC. The amount of overflow is only an estimate. No flow measurements were made during the 1986 flood.

(5) **Results** - The DWOPER calibration to the high water marks recorded in the NEMDC during the 1986 event are shown on Chart 30. No high water marks were available for the 1983 event in the NEMDC.

C. **YOLO BYPASS MODEL** - The Yolo Bypass model includes the Yolo Bypass from Fremont Weir to Lisbon and the Sacramento Bypass from the Sacramento Weir to the Yolo Bypass. The Yolo Bypass is the main stem and the Sacramento Bypass is a dynamic tributary.

(1) **Boundary Conditions** - The upper boundary inflow hydrographs to the Yolo Bypass and the Sacramento Bypass were computed with the Sacramento River model. These inflow hydrographs are the spills over the Fremont and Sacramento weirs, respectively. The observed stage hydrograph at Lisbon was used as the downstream boundary

condition. These inflow hydrographs are the computed hydrographs shown on Charts 30 and 31. The Lisbon stage hydrograph is shown on Chart 32.

(2) **N-Values** - N-values fell within the range used in the Sacramento River Model.

(3) **Lateral Inflows** - Lateral inflows consist of Cache Creek and Putah Creek. Other small streams contribute but were not considered.

(4) **Results** - The DWOPER calibrations to observed stage hydrographs and high water marks for the 1986 flood are shown on Chart 30. The only available data for the 1983 flood are shown on Chart 31.

4. SYNTHETIC FLOODS -

A. GENERAL - Water-surface elevations for the 100-, 200- and 400-year floods were computed for many locations in the basin using the Sacramento River, American River, and Yolo Bypass models.

B. CONCURRENCIES - Several historical events were reviewed to determine the concurrence of peak flows at the confluence of the Sacramento and American Rivers. The United States Geological Survey (USGS) Water Resources Data publications were used to obtain the maximum daily flows for the Sacramento River near Verona, American River at H Street, and Sacramento River at I Street gaging stations. The I Street gage was moved downstream to Freeport in October 1979. Table 11 shows the dates the maximum daily flows occured for each of the floods.

TABLE K-11

HISTORICAL FLOOD PEAK CONCURRENCIES

WATER YEAR	VERONA	H STREET	I STREET	FREEPORT
1955	12/23/55	12/24/55	12/23/55	
1956	1/17/56	1/17/56	1/17/56	
1964	12/25/64	12/24/64	12/14/64	
1983	1/30/83	1/28/83		1/29/83
	3/15/83	3/14/83		3/14/83
1986	2/20/86	2/19/86		2/19/86

The flood hydrographs are broad peaked. The difference between the peak flow on the day shown and the peak flow on the previous or next day is generally less than 5 percent.

(1) **100-Year** - The 100-year event was assumed to be concurrent over the entire study area. This assumption is based on the fact that many locations experienced a 70-year event and that it is not unreasonable to assume that a 100-year event could occur over the

area. The timing of the 100-year hydrographs is based on the timing of the flows that occurred during the 1986 event.

(2) **200-Year** - For the 200-year event, it was decided that having a 200-year event everywhere would result in an event actually greater than a 200-year event. Therefore, when a 200-year event was assumed to occur on one river a 100-year event was assumed concurrent over the rest of the area.

a. **Sacramento River** - The 200-year on the Sacramento River is assumed to be concurrent with a 100-year on the American River and a 100-year on all local streams. The timing of the peaks for the 200-year event is based on the timing of the 1986 event.

b. **American River** - The 200-year on the American River is assumed to be concurrent with a 100-year on the Sacramento River and a 100-year on all local streams. The timing of the 200-year event is based on the 1986 flood.

c. **Yolo Bypass** - The Yolo Bypass is a flood control bypass which accepts flow from the Sacramento and American Rivers. Therefore, concurrencies of the Sacramento and American Rivers affect the elevations in the Yolo Bypass.

(3) **400-Year** - For the 400-year event, it was decided that having a 400-year event everywhere would result in an event actually greater than a 400-year event. Therefore, when a 400-year event was assumed to occur on one river a 100-year event was assumed concurrent over the rest of the area.

a. **Sacramento River** - The 400-year on the Sacramento River is assumed to be concurrent with a 100-year on the American River and a 100-year on all local streams. The timing of the peaks for the 40C-year event is based on the timing of the 1986 event.

b. **American River** - The 400-year on the American River is assumed to be concurrent with a 100-year on the Sacramento River and a 100-year on all local streams. The timing of the 400-year event is based on the 1986 flood.

c. **Yolo Bypass** - The Yolo Bypass is a flood control bypass which accepts flow from the Sacramento and American Rivers. Therefore, concurrencies of the Sacramento and American Rivers affect the elevations in the Yolo Bypass.

C. SACRAMENTO RIVER MODEL -

(1) **Boundary Conditions** - The 100, 200- and 400-year hydrographs for the Sacramento River at Wilkins Slough, Sutter Bypass below Tisdale Weir, and Feather River below the Bear River were computed as part of the volume-frequency analysis described in Chapter III. The inflow to the Cross Canal was computed using HEC-1. The 100-, 200, and 400-year flows on the American River were computed as detailed in reference F. The flow-frequency curve for the American River, which shows the 100-, 200-, and 400-year peaks, is shown on Chart 4. The inflow hydrographs are shown on Charts 33, 34 and 35. A rating curve of flow vs. stage was used for all events as the downstream boundary at the Snodgrass Slough location. This rating curve was developed by plotting the 1986 stage vs. flow computed by DWOPER at the Snodgrass Slough location and then drawing a smooth curve through the points. The rating curve is shown on Chart 36.

(2) **N-Values** - N-values obtained in the calibration of the 1986 flood were used for the synthetic events.

(3) **Sacramento Weir** - The Sacramento Weir was modeled the same as in the reconstitution of the 1986 flood.

(4) **Fremont Weir** - As detailed above, for the 1986 flood, the Fremont Weir was at an effective elevation of 32.0 feet msl. Subsequent to the 1986 event, the State of California has removed approximately two-thirds of the sediment upstream of the weir and exposed the actual weir crest. Therefore, the effective elevation of the Fremont Weir for the synthetic events has been assumed to be 31.0 feet msl. This one foot change is two-thirds the difference between the 32.0 used for the 1986 and the actual sill elevation of 30.5 msl.

(5) **Nelson Bend** - The Nelson Bend structure was modeled the same as in the reconstitution of the 1986 flood.

(6) **Lateral Inflows** - Lateral inflows were treated the same as they were in the reconstitution of the 1986 flood.

D. AMERICAN RIVER MODEL -

(1) **Boundary Conditions** - The 100-, 200- and 400-year hydrographs were computed as detailed in reference F. These hydrographs were used as the upstream boundary for the American River. The upstream boundary for the NEMDC was computed using HEC-1 and the criteria listed in Chapter III. The downstream boundary for the American River was computed by the Sacramento River model.

(2) **N-Values** - The N-values verified for the 1986 flood were used for the synthetic events.

(3) **Lateral Inflows** - Lateral inflows consisted of Arcade Creek, Dry Creek, small tributaries in the Elverta drainage and pumping plants. The Arcade, Dry and Elverta inflows were computed by HEC-1 and the data described in Chapter III. All pumps were assumed to pump at full capacity throughout the duration of the flood. Total pumping capacity is approximately 1440 cfs.

(4) **Overflow From Natomas Cross Canal** - Based on estimates of flow splits in the Cross Canal drainage area for the 100-year flood, it was estimated that when the peak stages were occurring in the Natomas Cross Canal, a peak flow of approximately 760 cfs flowed from the Natomas Cross Canal drainage, over Sankey Road, and into the NEMDC drainage. This flow is only an estimate and should be treated that way. The 760 cfs was used for all events.

E. YOLO BYPASS MODEL -

(1) **Boundary Conditions** - The upper boundary 100-, 200-, and 400-year inflow hydrographs to the Yolo Bypass and the Sacramento Bypass were computed with the Sacramento River model. These inflow hydrographs vary greatly depending on assumed conditions in the basin (ie, increased upstream storage on the American River or levee improvements). They are too numerous to show in this report. However, Table 22 pages 64-68, lists the flows over Fremont and Sacramento weirs for a variety of conditions. A rating curve of flow vs. stage was used for all events as the downstream boundary at the Lisbon location. This rating curve was developed by plotting the 1986 stage vs. flow computed by DWOPER at the Lisbon location and then drawing a smooth curve through the points. The rating curve is shown on Chart 37.

(2) **N-Values** - N-values verified for the 1986 flood were used for the synthetic events.

(3) **Lateral Inflows** - Lateral inflows consist of Cache Creek and Putah Creek. Due to time and money constraints, and since their contributions are a small percentage of the total Yolo Bypass flow, the 100-year contributions from Cache and Putah Creeks were not computed. However, in order to have some local contribution from these streams in the DWOPER model, the 1986 flows were used as the 100-year inflows. Other small streams contribute but they were not considered.

F. SYNTHETIC FLOOD RESULTS - Stage-frequency curves and water-surface profiles for the study area are discussed in Chapter V.

G. **LEVEE FAILURE ASSUMPTIONS** - When extreme floods occur, levees have failed for unknown reasons, because of overtopping at low points or at known weak areas. A review of how each planning study defined levee failures revealed a number of different ideas. Table 12, page 38, details the assumptions used in breaching levees in the system for this hydraulics study. Levees are to be failed sequentially as the criteria are exceeded. Each location was failed in 1 hour with the maximum breach width being 200 feet. The breach width is based on evidence obtained from the 1986 levee failures on the Yuba River and the Mokelumne River. The bottom of the breach was held to the existing ground level on the land side of the levee. Flow through the breaks is computed using the weir formula of

$$FLOW=CLH^{1.5}$$

where C=the weir coefficient, L=breach width and H=the head difference between the River elevation and the bottom of the breach. DWOPER will check to see if submergence is a factor but only in certain situations will it keep track of the tailwater elevation. In cases where the tailwater has an effect but DWOPER cannot compute it, the weir coefficient was lowered to account for submergence that is not computed by DWOPER.

TABLE K-12

LEVEE FAILURE ASSUMPTIONS

LEVEE REACH	FREEBOARD (feet)
1. **RECLAMATION DISTRICT 1000**	
a. Sacramento River (Left Bank) - Natomas Cross Canal to Natomas Main Drain	3
b. Natomas Cross Canal (North and South Levees)	3
c. Natomas East Main Drain and South Levee to the Natomas Main Drain	3
2. **AMERICAN RIVER LEVEE SYSTEM**	
a. Right Bank, Sacramento River to River Mile 5.2	3
b. Right Bank, Upstream of River Mile 5.2	4
c. Left Bank, Sacramento River to River Mile 5.2	5
d. Left Bank, River Mile 5.2 to River Mile 7.8	5
e. Left Bank, Upstream of River Mile 7.8	4
3. **DRY CREEK, ARCADE CREEK, AND THE EAST LEVEE OF THE NATOMAS EAST MAIN DRAIN**	3
4. **SACRAMENTO RIVER (LEFT BANK) FROM THE AMERICAN RIVER TO FREEPORT**	3
5. **SACRAMENTO RIVER (RIGHT BANK) FROM THE SACRAMENTO BYPASS TO RIVERVIEW**	3
6. **YOLO BYPASS AND TRIBUTARY LEVEES**	3
7. **SACRAMENTO RIVER (RIGHT BANK) FROM THE NATOMAS CROSS CANAL TO THE SACRAMENTO BYPASS**	3

Due to constraints in the DWOPER program it was necessary to simulate failures of the Natomas Cross Canal by failing the right bank of the Sacramento River. It was also necessary to simulate west levee failures of the Natomas East Main Drain (NEMDC) by failing the north bank of the American River just downstream of where the NEMDC starts to parallel the American River.

Failures of the right (west) levee of the Sacramento River from the Natomas Cross Canal to the Sacramento Bypass will flood the area designated as Area C. This area, shown on Chart 1, is bounded by the Sacramento River on the north and east, the Sacramento Bypass on the south and the Yolo Bypass on the west. This area encompasses Reclamation Districts 1600, 827, 785, and part of 537.

Water flowing through failures in the right (north) levee of the American River will pond in the North Sacramento area behind the right bank levee up to elevation 36.0 feet. At elevation 36, the right bank levee will be overtopped and fail just upstream of the NEMDC. The water in the pond area will flow through the break and enter the American River. It was not possible to model this entire scenario using the DWOPER program. To model the right bank failures, three steps were taken.

First, the American River DWOPER model was run and the flows through the right bank failures were computed.

Second, the flows through the right bank failures were combined and ponded in the right bank until the pond reached elevation 36.0. The right bank pond elevation was computed by converting the inflow to storage and comparing the storage to the storage-elevation curve computed for the pond area. The storage-elevation curve was calculated from USGS 7.5 minute quadrangles. Once the elevation reached 36.0 the right bank levee was failed and the flow hydrograph through the break was computed by taking into account the head difference between the pond area and the American River.

Lastly, to include the effects of this return hydrograph, the American River DWOPER model was run again and the return flow hydrograph was included as a lateral flow.

CHAPTER V - STAGE-FREQUENCY CURVES AND WATER-SURFACE PROFILES

1. **GENERAL** - Stage-frequency curves and water-surface profiles were developed for a variety of levee failure assumptions and physical conditions throughout the study area. These curves and profiles were necessary to determine current levels of flood protection throughout the Sacramento Area and to determine the frequency of the 1986 event at various locations. They were also necessary to determine the benefits of the various project alternatives.

   Stage frequency curves were developed for (A) Sacramento River at West End Fremont Weir (location 38 on Chart 1), (B) Sacramento River at Verona (location 34 on Chart 1), (C) Sacramento River at I-Street (location 45 on Chart 1) , (D) American River at H-Street (location 44 on Chart 1), (E) Yolo Bypass at Woodland (location 40 on Chart 1), and (F) Yolo Bypass at Lisbon (location 49 on Chart 1). These curves are shown on Charts 38 through 43. Water-surface profiles were developed for the (A) Sacramento River, (B) Natomas Cross Canal, (C) American River, (D) Natomas East Main Drain (NEMDC), and (E) Yolo Bypass. The development of the stage-frequency curves is discussed in section 3 of this chapter.

   Water-surface profiles are shown on Charts 44 thru 60. These profiles represent different physical conditions. They are discussed in section 4 of this chapter. Comparisons of computed, 1986, and design water-surface profiles, shown an Charts 55 thru 60, and discussed in section 5 of this chapter.

2. **LEVEE FAILURE ASSUMPTIONS AND PHYSICAL CONDITIONS** - After looking at several different flow, levee failure and physical conditions, several areas popped up as the most likely to fail based on the freeboard criteria detailed in Chapter IV. Table 13 page 41, lists these locations.

TABLE K-13

LEVEE FAILURE LOCATIONS

#	LOCATION
1	Right (West) levee Sacramento River from Mile 78.5 to mile 72.5 (across river from Verona). Failures here flood Area C.
2	Right (West) levee Sacramento River from Mile 51 to 46 (West Sacramento)
3	Left (East) levee Sacramento River from Mile 54 to 46 (South Sacramento)
4	Left (South) levee American River in the vicinity of Mayhew Drain
5	Right (North) levee American River many locations from Arden Treatment Plant to H-Street
6	Right (North) levee American River downstream of Natomas East Main Drain
7	Right (West) levee Natomas East Main Drain upstream and downstream of El Camino
8	North (Right) levee Natomas Cross Canal approximately 1 mile upstream from the Sacramento River

As stated earlier, all breaks are sequential. When water flows through a break it is lost to the system. Currently, failures at locations 2 and 3 have not been modeled. Failures at these locations will be addressed in early 1990 as part of the continuing Sacramento Metropolitan Investigation. Therefore, stage-frequency curves at I-Street and water-surface profiles on the Sacramento River below the American River can be considered as the upper limit for the individual physical characteristics they each represent. The water-surface profiles presented on Chart 44 show the locations on the Sacramento River below the American River where the freeboard criteria are exceeded.

Also, no failures in the Yolo Bypass and Sacramento Bypass have been modeled. As with the Sacramento River, the water-surface profiles for the Yolo Bypass and Sacramento Bypass show where freeboard criteria is being exceeded. Failures in the Yolo Bypass will also be looked at in early 1990.

3. **STAGE-FREQUENCY CURVES AND WATER SURFACE PROFILES** -

During the course of this study it was necessary to determine the sensitivity of different types of projects. The projects ranged from levee improvements without an increase in available upstream storage to no levee improvements with an increase in upstream storage. The exact types of levee improvements were not considered. The approach taken was: If this location is fixed and that one isn't, what will the effects be. Several combinations were considered. The results of these combinations are displayed on the stage-frequency curves, Charts 38-43, and water-surface profiles, Charts 44-54 and on Table 22, pages 64-68. Also, results have been tabulated for combinations other than those displayed on the curves and profiles. These results are also shown on Table 22.

A. **SACRAMENTO RIVER AT THE WEST END OF FREMONT WEIR** - The curves for this location are shown on Chart 38. The numbers in parenthesis in each curve description denote the levee failure locations on Table 13, page 41. The 200- and 400- year elevations are the result of the 200- and 400-year events in the Sacramento River basin and a 100-year event elsewhere, as discussed in Chapter IV. The shape of the curves above the 200-year event is the result of levee failures upstream on the Feather River. These levee failures reduce the peak flow since the water spreads over the floodplain.

1. **CURVE NUMBER 1** - Curve number 1 represents existing conditions freeboard levee failures on the Sacramento River (1), on the American River (4,5) and on the NEMDC (7). For this curve, the effective weir crest of the Fremont Weir was 31.0 feet. The 200- and 400-year events also reflect levee failure on the American at location 7.

2. **CURVE NUMBER 2** - Curve number 2 represents existing conditions freeboard levee failures on the American River (4,5) and on the NEMDC (7). For this curve, the effective weir crest of the Fremont weir was 31.0 feet. The 200- and 400-year events also reflect levee failure on the American at location 7.

3. **CURVE NUMBER 3** - Curve number 3 represents project conditions with levee failures on the Sacramento River (1). Project conditions include levee improvements at all locations except location 1 and an increase in upstream storage so that the objective release from Folsom will be 115,000 cfs for all events.

4. **CURVE NUMBER 4** - Curve number 4 represents project conditions with no levee failures anywhere. Project conditions include levee improvements at all locations and an increase in upstream storage so that the objective release from Folsom will be 115,000 for all events.

5. **CURVE NUMBER 5** - Curve number 5 represents existing conditions freeboard levee failures on the Sacramento River (1), on the American River (4,5) and on the NEMDC (7). For this curve, the effective weir crest of the Fremont Weir was 32.0 feet. The 200- and 400-year events also reflect levee failure on the American at location 7.

6. **CURVE NUMBER 6** - Curve number 6 represents existing conditions freeboard levee failures on the American River (4,5) and on the NEMDC (7). For this curve, the effective weir crest of the Fremont Weir was 32.0 feet. This sediment elevation reflects the estimated effective weir crest during the 1986 flood and results in higher elevations downstream of Fremont Weir and upstream of Sacramento Weir. The 200- and 400-year events also reflect levee failure on the American River at location 7.

7. **CURVE NUMBER 7** - Curve number 7 is a preproject condition curve which represents freeboard failures on the South levee of the Natomas Cross Canal, on the American River (4,5) and on the NEMDC (7). The weir crest of Fremont Weir was at 30.5 (all sediment has been removed). The south levee of the Natomas Cross Canal does not fail at the 100-year level, only at the 200 and 400-year events. Table 23 lists the elevations at various locations in the area for the above mentioned conditions.

B. **SACRAMENTO RIVER AT VERONA** - The curves for this location are shown on Chart 39. The numbers in parenthesis in each curve description denote the levee failure locations on Table 13, page 41. The 200- and 400- year elevations are the result of the 200- and 400-year events in the Sacramento River basin and a 100-year event elsewhere, as discussed in Chapter IV. The shape of the curves above the 200-year event is the result of levee failures upstream on the Feather River. These levee failures reduce the peak flow since the water spreads over the floodplain.

1. **CURVE NUMBER 1** - Curve number 1 represents existing conditions freeboard levee failures on the Sacramento River (1), on the American River (4,5) and on the NEMDC (7). For this curve, the effective weir crest of the Fremont Weir was 31.0 feet. The 200- and 400-year events also reflect levee failure on the American at location 7.

2. **CURVE NUMBER 2** - Curve number 2 represents existing conditions freeboard levee failures on the American River (4,5) and on the NEMDC (7). For this curve, the effective weir crest of the Fremont Weir was 31.0 feet. The 200- and 400-year events also reflect levee failure on the American at location 7.

3. **CURVE NUMBER 3** - Curve number 3 represents project conditions with levee failures on the Sacramento River (1). Project conditions include levee improvements at all locations except location 1 and an

increase in upstream storage so that the objective release from Folsom will be 115,000 cfs for all events.

4. **CURVE NUMBER 4** - Curve number 4 represents project conditions with no levee failures anywhere. Project conditions include levee improvements at all locations and an increase in upstream storage so that the objective release from Folsom will be 115,000 for all events.

5. **CURVE NUMBER 5** - Curve number 5 represents existing conditions freeboard levee failures on the Sacramento River (1), on the American River (4,5) and on the NEMDC (7). For this curve, the effective weir crest of the Fremont Weir was 32.0 feet. The 200- and 400-year events also reflect levee failure on the American at location 7.

6. **CURVE NUMBER 6** - Curve number 6 represents existing conditions freeboard levee failures on the American River (4,5) and on the NEMDC (7). For this curve, the effective weir crest of the Fremont weir was 32.0 feet. This sediment elevation reflects the estimated effective weir crest during the 1986 flood and results in higher elevations downstream of Fremont Weir and upstream of Sacramento Weir. The 200- and 400-year events also reflect levee failure on the American at location 7.

7. **CURVE NUMBER 7** - Curve number 7 is a preproject condition curve which represents freeboard failures on the South levee of the Natomas Cross Canal, on the American River (4,5) and on the NEMDC (7). The weir crest of Fremont Weir was at 30.5 (all sediment has been removed). The south levee of the Natomas Cross Canal does not fail at the 100-year level, only at the 200 and 400-year events. Table 23 lists the elevations at various locations in the area for the above mentioned conditions.

C. **SACRAMENTO RIVER AT I-STREET** - The curves for this location are shown on Chart 40. The shape of curves 1, 2, 5 and 6 reflect the shape of the peak flow frequency curve for the American River at Fair Oaks. Under existing conditions, Folsom will loose control at the 63-year level. This loss of control affects the I-Street location, as the above mentioned curves rise sharply at the 63-year level. Curves 1, 2, 5 and 6 follow the general shape of the American River curve shown on Chart 5. The numbers in parenthesis in each curve description denote the levee failure locations on Table 13, page 41.

Curves 1, 2, 5, and 6 do not reflect any levee failures on the Sacramento River downstream of the American River. Events on the American River which cause these high elevations will result in freeboard criteria being exceeded, and in some cases, levees overtopped. However, due to time constraints, it was not possible to include these failures in the Sacramento River DWOPER model. Therefore, the levees on the Sacramento River downstream of the American River are considered infinitely high and curves 1, 2, 5, and 6 reflect this condition. Locations on this reach of the Sacramento River where freeboard is exceeded can be seen on water-surface profiles, Chart 44.

1. **CURVE NUMBER 1** - Curve number 1 represents existing conditions freeboard levee failures on the Sacramento River (1), on the American River (4,5) and on the NEMDC (7). For this curve, the effective weir crest of the Fremont Weir was 31.0 feet. The 200- and 400-year events also reflect levee failure on the American at location 7.

2. **CURVE NUMBER 2** - Curve number 2 represents existing conditions freeboard levee failures on the American River (4,5) and on the NEMDC (7). For this curve, the effective weir crest of the Fremont Weir was 31.0 feet. The 200- and 400-year events also reflect levee failure on the American at location 7.

3. **CURVE NUMBER 3** - Curve number 3 represents project conditions with levee failures on the Sacramento River (1). Project conditions include levee improvements at all locations except location 1 (Area C) and an increase in upstream storage so that the objective release from Folsom will be 115,000 cfs for all events.

4. **CURVE NUMBER 4** - Curve number 4 represents project conditions with no levee failures anywhere. Project conditions include levee improvements at all locations and an increase in upstream storage so that the objective release from Folsom will be 115,000 for all events.

5. **CURVE NUMBER 5** - Curve number 5 represents existing conditions freeboard levee failures on the Sacramento River (1), on the American River (4,5) and on the NEMDC (7). For this curve, the effective weir crest of the Fremont Weir was 32.0 feet. The 200- and 400-year events also reflect levee failure on the American at location 7.

6. **CURVE NUMBER 6** - Curve number 6 represents existing conditions freeboard levee failures on the American River (4,5) and on the NEMDC (7). For this curve, the effective weir crest of the Fremont Weir was 32.0 feet. The 200- and 400-year events also reflect levee failure on the American at location 7.

D. **<u>AMERICAN RIVER AT H-STREET</u>** - The curves for this location are shown on Chart 41. These curves reflect Folsom Dam being operated according to the flood control diagram up to the release given for each curve. The numbers in parenthesis in each curve description denote the levee failure locations on Table 13, page 41.

1. **CURVE NUMBER 1** - Curve number 1 represents existing conditions freeboard levee failures on the Sacramento River (1), on the American River (4,5) and on the NEMDC (7). For this curve, the effective weir crest of the Fremont Weir was 31.0 feet. The 200- and 400-year events also reflect levee failure on the American at location 7.

   The 100-year stage was computed using a 100-year event over the entire basin. The 200- and 400-year stages were computed using the 200- and 400-year events on the American River and a 100-year event elsewhere. The 100-year release from Folsom is 234,000 cfs. The 200-year release from Folsom is 432,000 cfs. The 400-year release from Folsom is 543,000 cfs. Concurrencies are discussed in Chapter IV.

2. **CURVE NUMBER 2** - Curve number 2 represents project conditions with no levee failures anywhere. Project conditions include levee improvements at all locations and an increase in upstream storage so that the objective flow in the American River will be 115,000 for the 100- through 400-year events. This flow is concurrent with the 100-year event on Sacramento River and all local streams.

3. **CURVE NUMBER 3** - Curve number 3 represents project conditions with no levee failures anywhere. Project conditions include levee improvements at all locations and an increase in upstream storage so that the objective flow in the American River will be 130,000 for the 100- through 400-year events. This flow is concurrent with the 100-year event on Sacramento River and all local streams.

4. **CURVE NUMBER 4** - Curve number 4 represents project conditions with no levee failures anywhere. Project conditions include levee improvements at all locations and an increase in upstream storage so that the objective flow in the American River will be 180,000 for the 100- through 400-year events. This flow is concurrent with the 100-year event on Sacramento River and all local streams.

5. **CURVE NUMBER 5** - Curve number 5 represents existing conditions freeboard levee failures on the Sacramento River (1), on the American River (4,5) and on the NEMDC (7). The flow in the American River will be 180,000 for the 100- through 400-year events. This flow is concurrent with the 100-year event on Sacramento River and all local streams.

E. **YOLO BYPASS AT WOODLAND** - The curves for this location are shown on Chart 42. The numbers in parenthesis in each curve description denote the levee failure locations on Table 13, page 41. These curves do not reflect any levee failures or overtopping in the Yolo Bypass or any tributaries. Locations where freeboard criteria is exceeded can be seen on the water-surface profiles, Chart 47.

When looking at Chart 42, you will see that curves 3 and 5 cross. This is because they are derived from a different set of physical characteristics which result in different flow regimes over the Fremont and Sacramento Weirs.

1. **CURVE NUMBER 1** - Curve number 1 represents existing conditions freeboard levee failures on the Sacramento River (1), on the American River (4,5) and on the NEMDC (7). For this curve, the effective weir crest of the Fremont Weir was 31.0 feet. The 200- and 400-year events also reflect levee failure on the American at location 7.

2. **CURVE NUMBER 2** - Curve number 2 represents existing conditions freeboard levee failures on the American River (4,5) and on the NEMDC (7). For this curve, the effective weir crest of the Fremont Weir was 31.0 feet. The 200- and 400-year events also reflect levee failure on the American at location 7.

3. **CURVE NUMBER 3** - Curve number 3 represents project conditions with levee failures on the Sacramento River (1). Project conditions include levee improvements at all locations except location 1 and an increase in upstream storage so that the objective release from Folsom will be 115,000 cfs for all events.

4. **CURVE NUMBER 4** - Curve number 4 represents project conditions with no levee failures anywhere. Project conditions include levee improvements at all locations and an increase in upstream storage so that the objective release from Folsom will be 115,000 for all events.

5. **CURVE NUMBER 5** - Curve number 5 represents existing conditions freeboard levee failures on the Sacramento River (1), on the American River (4,5) and on the NEMDC (7). For this curve, the effective weir crest of the Fremont Weir was 32.0 feet. The 200- and 400-year events also reflect levee failure on the American at location 7.

6. **CURVE NUMBER 6** - Curve number 6 represents existing conditions freeboard levee failures on the American River (4,5) and on the NEMDC (7). For this curve, the effective weir crest of the Fremont Weir was 32.0 feet. The 200- and 400-year events also reflect levee failure on the American at location 7.

7. **CURVE NUMBER 7** - Curve number 7 is a preproject condition curve which represents freeboard failures on the South levee of the Natomas Cross Canal, on the American River (4,5) and on the NEMDC (7). The weir crest of Fremont Weir was at 30.5 (all sediment has been removed). The south levee of the Natomas Cross Canal does not fail at the 100-year level, only at the 200 and 400-year events. Table322 lists the elevations at various locations in the area for the above mentioned conditions.

F. YOLO BYPASS AT LISBON - The curves for this location are shown on Chart 43. The numbers in parenthesis in each curve description denote the levee failure locations on Table 13, page 41. These curves do not reflect any levee failures or overtopping in the Yolo Bypass or any tributaries. Locations where freeboard criteria is exceeded can be seen on the water-surface profiles, Chart 47.

1. **CURVE NUMBER 1** - Curve number 1 represents existing conditions freeboard levee failures on the Sacramento River (1), on the American River (4,5) and on the NEMDC (7). For this curve, the effective weir crest of the Fremont Weir was 31.0 feet. The 200- and 400-year events also reflect levee failure on the American at location 7.

2. **CURVE NUMBER 2** - Curve number 2 represents existing conditions freeboard levee failures on the American River (4,5) and on the NEMDC (7). For this curve, the effective weir crest of the Fremont weir was 31.0 feet. The 200- and 400-year events also reflect levee failure on the American at location 7.

3. **CURVE NUMBER 3** - Curve number 3 represents project conditions with levee failures on the Sacramento River (1). Project conditions include levee improvements at all locations except location 1 and an increase in upstream storage so that the objective release from Folsom will be 115,000 cfs for all events.

4. **CURVE NUMBER 4** - Curve number 4 represents project conditions with no levee failures anywhere. Project conditions include levee improvements at all locations and an increase in upstream storage so that the objective release from Folsom will be 115,000 for all events.

5. **CURVE NUMBER 5** - Curve number 5 represents existing conditions freeboard levee failures on the Sacramento River (1), on the American River (4,5) and on the NEMDC (7). For this curve, the effective weir crest of the Fremont weir was 32.0 feet. The 200- and 400-year events also reflect levee failure on the American at location 7.

6. **CURVE NUMBER 6** - Curve number 6 represents existing conditions freeboard levee failures on the American River (4,5) and on the NEMDC (7). For this curve, the effective weir crest of the Fremont Weir was 32.0 feet. The 200- and 400-year events also reflect levee failure on the American at location 7.

7. **CURVE NUMBER 7** - Curve number 7 is a preproject condition curve which represents freeboard failures on the South levee of the Natomas Cross Canal, on the American River (4,5) and on the NEMDC (7). The weir crest of Fremont Weir was at 30.5 (all sediment has been removed).

The south levee of the Natomas Cross Canal does not fail at the 100-year level, only at the 200 and 400-year events. Table 23 lists the elevations at various locations in the area for the above mentioned conditions.

4. **COMPUTED WATER-SURFACE PROFILES** - Charts 44-54 show water-surface profiles for various conditions. These profiles represent the frequency curves described above and the numbers tabulated on Table 22, pages 64-68. The profiles are helpful in determining where freeboard criteria have been exceeded and in visually comparing the differences in water-surfaces resulting from the various alternatives. The profiles represent preproject and project conditions.

   For the Sacramento River, Natomas Cross Canal, Yolo Bypass and Sacramento Bypass the legend for each profile lists the filename on Table 22 (each filename represents a specific DWOPER computer run) which the respective profile represents. The profiles representing runs which begin with DME3 are preproject profiles. These profiles show the effects of levee failures based on the freeboard criteria from Table 12, page 38. They reflect 100-, 200-, and 400-year flows on the Sacramento River and a 100-year flow (234,000 cfs) on the American River. When a 200- or 400-year event is occurring on the American River concurrently with the 100-year on the Sacramento River, flows and stages will be higher in the Sacramento River and Yolo Bypass below the Sacramento Bypass. To see this difference, compare runs DME310B1, DME320B1, DME340B1, DME320D1 and DME340F1 on Table 22.

   The profiles representing runs which begin with DME5 are project profiles. These profiles show the effects of no levee failures and a flow of 115,000 cfs in the American River. Natomas Cross Canal profiles are the same for both conditions.

   For the American River and Natomas East Main Drain the 100-, 200-, and 400-year profiles represent preproject condition flows with levee failures based on criteria in Table 12. Profiles representing flows of 115,000, 130,000, and 180,000 cfs represent project conditions with no levee failures.

5. **DESIGN WATER SURFACE PROFILES** - Design water-surface profiles for the Sacramento River, Yolo Bypass Sacramento Bypass, Natomas Cross Canal, American River and NEMDC are shown on Charts 55-60. This Chart shows the design, 1986 computed and 100-year computed water-surface profiles. The design elevations are those which were used to originally design the Sacramento River Flood Control System. The 1986 profiles were computed by the DWOPER model. The 100-year profiles are taken from run DME310B1 on Table 22.

6. **FREMONT WEIR MODIFICATIONS** - One alternative looked at during the course of this study is the widening of Fremont Weir. Under this proposal, Fremont weir and Yolo Bypass would be widened to the east in order to allow more water to flow over the Fremont Weir and less water down the Sacramento River past Verona. Less water flowing down the Sacramento River would decrease water surface elevations in the Sacramento River and the Natomas Cross Canal. Lowering water in the Natomas Cross Canal would lower water levels in the Pleasant Grove level, mitigating the effects of any levee raising projects on the Natomas Cross Canal. The widening of Fremont Weir would not alleviate the existing flooding problem in the Pleasant Grove area.

To simulate this widening using DWOPER, the cross-sections of the Yolo Bypass were adjusted. At the Fremont Weir, the bypass was widened 1000 feet. From this point the sections were tapered back to match the existing width approximately 2.2 miles downstream of Fremont Weir. Table 23 ,page 67, shows the effects of wideneing the weir.

CHAPTER VI - AUBURN DAM

1. **GENERAL** - This chapter presents the development of the Probable Maximum Flood (P.M.F.) inflow hydrograph for the North Fork of the American River above the Auburn Dam site. This P.M.F. hydrograph will be used to size the spillway for that dam.

2. **PREVIOUS STUDIES** - The last P.M.F. report for the American River was completed in 1980 for Folsom Reservoir, published in the September 1980 Office Report, "American River Basin, California, Folsom Dam Spillway Adequacy Studies, Hydrology", revised July 1983 by Sacramento District, Corps of Engineers, Sacramento, California. The 1980 report used criteria presented in Hydrometeorological Report (H.M.R.) No. 36. to center the storm above Folsom Dam (1860 sq. mi.). The snow depths and densities and HEC-1 model used in the 1980 study were used in this report. This report uses new precipitation depth data from H.M.R. No. 36 for the North and Middle Forks of the American River above the Auburn Dam site (Auburn Centering).

3. **DESCRIPTIVE INFORMATION** -

   A. **LOCATION** - The Auburn Dam site is on the North Fork of the American River approximately 17 miles upstream from Folsom Dam and has a drainage area of 973 square miles (see Chart 61).

   B. **TOPOGRAPHY** - Elevation ranges from over 10,000 feet at the headwaters to 490 feet at the Auburn Dam site. Charts 62 and 63 show the stream profiles for the North and Middle forks of the American River above Folsom Reservoir.

   C. **NORMAL ANNUAL PRECIPITATION (NAP)** - NAP for the drainage basin varies considerably, as illustrated in Chart 64 ranging from about 35 inches at the Auburn Dam site to over 80 inches along the ridge separating the North and Middle forks of the American River.

   D. **OTHER RESERVOIRS** - There are over 20 dams above the Auburn Dam site listed in the U.S.C.E. inventory of dams. Eight of these were determined to be large enough to have an impact on P.M.F. inflow to the dam and therefore were considered in the development of the model for routing the P.M.F. to the Auburn Dam site. A list of these eight dams can be found in Table 14, page 52.

4. **HISTORICAL FLOOD ANALYSIS** - All the data presented in this section were used in developing the HEC model for this report and the 1980 Folsom report.

   Four historical flood events for the area above Folsom Dam were studied. They occurred 28 January to 3 February 1963, 20-24 December 1964, 18-23 January 1969 and 8-18 January 1980. The first two floods were analyzed in

TABLE K-14

NORTH FORK AMERICAN RIVER BASIN, CALIFORNIA
RESERVOIR ROUTING
SUMMARY OF STORAGE-OUTFLOW RELATIONSHIPS

NAME OF DAM / SUBAREA NUMBER	NORTH FORK DAM 4270	L. L. ANDERSON DAM 4275	RUBICON SPRINGS DAM 4280	HELL HOLE DAM 4288	LOON LAKE DAM 4295	GERLE DIVERSION DAM 4300 1/	STUMPY MEADOWS DAM 4318	RALSTON AFTERBAY 4333
Top of Dam Elev. (Feet)	718.0	5,271.0	6,251.0	4,650.0	6,418.0	5,240.5	4,272.0	1,189.0
Spillway Crest Elev. (Feet)	720.0	5,244.5	6,245.9	4,630.0	6,410.0	5,230.4	4,262.0	1,149.0
Initial Storage (Ac ft) 2/	10,600	111,605	1,700	207,600	76,200	1,380	20,000	850
Initial Elev. (Feet)	718.0	5,244.5	6,245.9	4,630.0	6,410.0	5,230.4	4,262.0	1,149.0
Operating Agency 3/	USCE	PCWA	SMUD	PCWA	SMUD	SMUD	GPUD	PCWA

	North Fork STORAGE (Ac-ft)	North Fork OUTFLOW (cfs)	L. L. Anderson STORAGE (Ac-ft)	L. L. Anderson OUTFLOW (cfs)	Rubicon Springs STORAGE (Ac-ft)	Rubicon Springs OUTFLOW (cfs)	Hell Hole STORAGE (Ac-ft)	Hell Hole OUTFLOW (cfs)	Loon Lake STORAGE (Ac-ft)	Loon Lake OUTFLOW (cfs)	Gerle Diversion STORAGE (Ac-ft)	Gerle Diversion OUTFLOW (cfs)	Stumpy Meadows STORAGE (Ac-ft)	Stumpy Meadows OUTFLOW (cfs)	Ralston Afterbay STORAGE (Ac-ft)	Ralston Afterbay OUTFLOW (cfs)
	10,400	0	0	0	60	2	201,376	0	62,700	565	920	0	2,400	0	0	0
	10,600	0	.629	8	90	4	207,590	1	76,200	591	1,100	600	3,600	2	50	5
	10,800	560	2,788	8	240	8	210,104	3,500	77,600	1,200	1,210	2,150	5,000	5	200	10
	11,000	1,600	3,846	8	915	13	212,633	8,000	79,000	2,575	1,330	6,300	10,800	10	500	20
	11,250	3,100	6,832	8	1,450	15	215,178	17,500	80,500	3,980	1,360	9,170	20,000	18	840	25
	11,500	6,000	8,754	8	1,570	1,500	216,457	22,500	82,000	6,055	1,430	12,600	20,800	1,600	1,400	25,000
	11,700	10,300	10,804	8	1,700	6,200	217,739	27,500	85,000	13,680	1,530	22,000	21,500	4,900	2,050	70,000
	12,200	22,200	23,743	8	1,825	13,000	220,315	39,000	88,000	24,700	1,610	33,900	22,500	9,600	2,850	131,000
	13,300	67,000	82,447	8	1,960	21,000	224,468	58,800			1,740	47,100	23,000	20,700	3,220	159,000
	14,700	100,000	110,871	8	2,235	41,000	225,513	64,500			1,860	66,200	25,000	25,000	3,700	202,000
			111,602	8	2,370	53,000	230,769	90,000							5,000	270,000
			118,678	1,740			233,420	103,000							6,500	340,000
			125,331	4,720			236,000	115,000								
			132,182	8,260												
			136,405	10,480												
			148,000	16,300												
			155,400 E	18,800 E												
			157,800 E	22,600 E												
			180,300 E	33,000 E												

1/ Storage-outflow relationship for Gerle Diversion Dam is combined with that of Robbs Peak Diversion Dam.

2/ Initial storage and elevation are the starting storage and water surface elevations at the beginning of the PMF.

3/ Operating Agencies: USCE - U.S. Army Corps of Engineers; PCWA - Placer County Water Agency; SMUD - Sacramento Municipal Utility District; GPUD - Georgetown Public Utility District; PG&E - Pacific Gas and Electric Company.

4/ E - Estimated.

detail to verify unit hydrographs and obtain loss rates, routing, and base flow criteria used to calibrate the basin model as a whole for developing the P.M.F. The analysis was made by developing a mathematical model of the basin using the U.S.C.E. computer program, "HEC-1 Flood Hydrograph Package." Portions of the last two events were studied for the same reason. Not enough data were available for a full analysis of the 1969 and 1980 floods at Folsom Dam.

The basin above Folsom Dam was divided into subareas. These divisions were made at upstream dams and stream gages to facilitate analysis of the historical flood events and development of the P.M.F. Subareas for the North and Middle forks of the American River are shown on Chart 65.

Subarea precipitation amounts for the historical storms were developed from isohyetal maps based on precipitation amounts recorded at official gages in the basin. Time distribution of precipitation was based on records at one or more recording precipitation stations (Chart 64 shows the locations of the precipitation stations).

Antecedent snowpack can produce runoff in the upper basins. For instance, prior to the January 1963 storm, snow depth varied from no snow at 6,000 feet to 6 inches at 9,000 feet, with an estimated density of 44 percent. This snowpack had little effect on excess, while the wet snowpack prior to the December 1964 storm added excess to the storm precipitation. This snowpack varied from zero inches at 4,000 feet to over 60 inches above 9,000 feet, with densities varying from 40 percent at 6,000 feet to 25 percent at 10,000 feet. Snowmelt analysis was not done for the 1969 and 1980 floods.

Potential snowmelt rates were computed for each 1,000-foot elevation band within each subarea by use of the melt equation for rain-on-snow conditions and partly forested areas given in EM 1110-2-1406. Temperature data for use in this equation were based on the records for Central Sierra Snow Laboratory, Blue Canyon, and Twin Lakes weather stations. A lapse rate of 3 degrees F per 1,000 feet was used for both storms.

The influence of the snowpack on runoff was determined using a computer program using computational procedure developed by the Bureau of Reclamation and described in Engineering Monograph No. 35, "Effect of Snow Compaction on Runoff from Rain on Snow," dated June 1966. The procedure is basically a water-budget analysis that accounts for the water in the snowpack until it is released as runoff. The procedure uses the concept of "threshold density" and recognizes the compaction (shrinkage) of the snowpack as water is added. The "threshold density" (defined as the density of the snowpack at which compaction ceases and runoff from the pack begins) used was 44% and 40%, respectively, for the January 1963 and December 1964 storms.

Unit hydrographs for this study were developed using the modified Los Angeles District S-curve procedure presented in Technical Bulletin No. 5-550-3, "Flood Production Techniques," dated February 1957. S-curves and (n) parameters were developed from the unit hydrographs used for the 1965 study of the December 1964 Hell Hole Dam failure. These parameters were verified by reconstitutions of the January 1963 and December 1964 flood runoff into Folsom Reservoir. S-curves and lag relationships are shown on Charts 66 and 67, respectively.

Unit hydrographs with higher peaks and shorter lag times were developed for computation of the Probable Maximum Flood to explain the increased hydraulic efficiency of the basins during this type of event. These adjustments were accomplished by reducing n values by 20%, which produced a corresponding change in peak flows and lag times.

Basin average constant loss rates varied for the different reconstituted floods, as shown below.

Storm	Basin Average Constant Loss (in/hr)
January 1963	.12
December 1964	.16
January 1969	.08
January 1980	.09

As a result of these storm studies, 0.10 inch per hour was adopted as a basin average loss rate for the P.M.F. No initial loss rate was used; it was assumed that wet ground conditions prevailed at the beginning of the P.M.F.

The beginning base flow used for each subarea was the observed flow of that particular basin at the beginning of each historical storm. Recession values were based on observed hydrographs. Base flows for the P.M.F. consisted of a rate of one cfs per square mile. The recession following the peak was based on ratios of base flow to peak, derived from the January 1963 and December 1964 flood reconstitutions.

A flood routing diagram for the study area is shown on Chart 68. The Muskingum Routing Method was used for all the stream routing reaches. The operating procedures and storage discharge curves used for routing through the upstream reservoirs were provided by the different operating agencies. See Table 14, page 52, for storage-discharge relationships.

Reconstitutions of the January 1963 and December 1964 inflow hydrographs to Folsom Reservoir are shown on Chart 69. These reconstitutions are considered to be satisfactory and serve to verify the unit hydrograph, loss rates, base flow, and flood routing criteria. Accordingly, the mathematical model of the basin is considered adequate for computation of the P.M.F. inflow to the Auburn Dam site.

5. **PROBABLE MAXIMUM FLOOD** -

The general rain Probable Maximum Precipitation (P.M.P.) was determined by using "H.M.R. No. 36, Interim Report - P.M.P. in California" and revisions thereto dated October 1969. The January-February period was adopted for computation of the general rain P.M.P. because it produced the highest precipitation. General rain P.M.P. for a 72-hour storm centered over the basin above the Auburn Dam site is 36.27 inches. An isohyetal map of the Probable Maximum Storm is shown on Chart 70. This map reflects orographic and convergence precipitation based on NAP.

A snowpack normally is present on the American River Basin during the winter time. Accordingly, a wet snowpack was assumed to exist prior to the P.M.P. The snowpack used was equivalent to the December 1964 pack, chosen for its moderate pack and high densities.

Potential snowmelt rates were computed for each 1,000 foot elevation band within each subarea by use of the melt equation for rain-on-snow conditions and partly forested areas given in EM 1110-2-1406. Precipitation distribution, wind, and temperature data for use in this equation were based on the criteria presented in H.M.R. 36. The P.M.P. subarea amounts found in the 1980 Folsom Dam Report were increased by 2.84 percent to reflect the basin average 36.27 inches requirement from H.M.R. 36. Precipitation was assumed to fall as rain when temperatures were above 32 degrees F.

The influence of the snowpack on P.M.F. runoff was determined using the computational procedure described in paragraph 4. Snowmelt over the entire basin contributed 2.59 inches of water with 0.54 inch of rain absorbed by the snow. Total P.M.P. excess water before losses is 38.32 inches. See Table 15, page 56, for final subarea and average basin precipitation depths.

The P.M.F. inflow to the Auburn Dam site was computed using the previously described basin model and P.M.P. storm plus snowmelt. Routings through upstream reservoirs were made assuming starting storage at gross pool or spillway crest as shown on Table 14, page 52. During the P.M.F. routing, five of the eight dams upstream in the model passed the flood through their spillways without being overtopped. North Fork Dam on the North Fork American River, Ralston Afterbay and L. L. Anderson Dam on the Middle Fork American River were overtopped. Both North Fork Dam and Ralston Afterbay are concrete structures that have been overtopped before without failure and were not failed in these routings. L. L. Anderson Dam is a composite gravel and earthfill structure 231 feet high. The crest of L. L. Anderson Dam varies from 5,271 feet at each abutment to 5,275 feet at its center.

TABLE K-15

EXCESS WATER BEFOR LOSSES
RAIN AND SNOWMELT DEPTHS
FOR SUBAREAS

	SUBAREA NUMBERS (See Chart 8 for location of subareas)																PER ELEV. BAND TOTAL
	2	3	4	6	9	120	15	16	17	21	22	23	24	25	27	281	
0-1000 (Ft. elev.)																	
D.A. (sq.mi.)	4.00														7.00	4.20	15.20
Rain Fall (in.)	25.30														25.71	21.60	24.47
Rain Absorbed (in.)	0														0.00	0.00	0.00
Snowmelt (in.)	0														0	0	0.00
TOTAL (in.)	25.30														25.71	21.60	24.47
1001-2000(Ft. elev.)																	
D.A. (sq.mi.)	29.30										2.70	2.50	5.30		22.90	12.70	75.40
Rain Fall (in.)	27.66										30.34	30.34	30.03		26.33	22.73	26.78
Rain Absorbed (in.)	0										0	0	0		0	0	0.00
Snowmelt (in.)	0										0	0	0		0	0	0.00
TOTAL (in.)	27.66										30.34	30.34	30.03		26.33	22.73	26.78
2001-3000(Ft. elev.)																	
D.A. (sq.mi.)	64.10										10.60	6.50	7.60	10.00	30.80	0.10	129.70
Rain Fall (in.)	30.65										31.47	31.26	30.34	29.82	29.31	25.71	30.34
Rain Absorbed (in.)	0										0	0	0	0	0	0	0.00
Snowmelt (in.)	0										0	0	0	0	0	0	0.00
TOTAL (in.)	30.65										31.47	31.26	30.34	29.82	29.31	25.71	30.34
3001-4000(Ft. elev.)																	
D.A. (sq.mi.)	65.50			3.00							23.30	16.00	10.00	2.50	16.00		136.30
Rain Fall (in.)	33.42			34.97							33.42	32.91	31.88	31.88	33.11		33.22
Rain Absorbed (in.)	0			0							0	0	0	0	0		0.00
Snowmelt (in.)	1			1.00							1.00	1.00	1.00	1.00	1.00		1.00
TOTAL (in.)	34.42			35.97							34.42	33.91	32.88	32.88	34.11		34.22
4001-5000(Ft. elev.)																	
D.A. (sq.mi.)	49.20			10.80		5.00		0.10	4.40	6.80	57.30	31.50	7.30		1.80		174.20
Rain Fall (in.)	36.51			37.54		37.54		38.57	38.05	37.02	36.30	36.51	34.45		33.42		36.48
Rain Absorbed (in.)	0			0		0		0	0	0	0	0	0		0		0.00
Snowmelt (in.)	3.40			3.40		3.40		3.40	3.40	3.40	3.40	3.40	3.40		3.40		3.40
TOTAL (in.)	39.91			40.94		40.94		41.96	41.45	40.42	39.70	39.91	37.85		36.82		39.88
5001-6000(Ft. elev.)																	
D.A. (sq.mi.)	50.60	15.20	1.70	14.20		9.50		17.90	6.60	6.90	25.90	25.40	2.10				176.00
Rain Fall (in.)	40.83	42.16	43.19	40.52		38.05		39.08	39.08	39.28	38.05	40.83	39.08				40.06
Rain Absorbed (in.)	0	0	0	0		0		0	0	0	0	0	0				0.00
Snowmelt (in.)	5.29	5.39	5.24	5.27		5.09		5.17	5.17	5.18	5.09	5.29	5.17				5.23
TOTAL (in.)	46.12	47.55	48.43	45.79		43.14		44.25	44.25	44.46	43.14	46.12	44.25				45.29
6001-7000(Ft. elev.)																	
D.A. (sq.mi.)	59.80	20.20	7.40	1.90	5.00	31.50	7.40	16.80	0.70	4.20	2.70	6.90					164.50
Rain Fall (in.)	43.40	42.99	43.71	43.09	38.05	38.87	40.11	40.11	39.08	41.65	38.57	45.76					41.80
Rain Absorbed (in.)	0.32	0.32	0.32	0.32	0.32	0.32	0.32	0.32	0.32	0.32	0.32	0.32					0.32
Snowmelt (in.)	4.00	3.98	4.02	3.98	3.68	3.76	3.63	3.83	3.77	3.91	3.74	4.12					3.91
TOTAL (in.)	47.08	46.65	47.41	46.75	41.41	42.31	43.42	43.62	42.53	45.24	41.99	49.56					45.39
7001-8000(Ft. elev.)																	
D.A. (sq.mi.)	17.60	10.30	0.80	0.10	15.60	30.70	0.60	4.40		0.10	0.20	0.10					80.50
Rain Fall (in.)	42.27	43.71	43.71	46.28	38.57	40.11	40.11	40.62		42.16	38.57	46.79					40.82
Rain Absorbed (in.)	1.32	1.32	1.32	1.34	1.32	1.32	1.32	1.32		1.32	1.32	1.34					1.32
Snowmelt (in.)	2.46	2.51	2.51	2.61	2.34	2.39	2.39	2.41		2.46	2.34	2.63					2.41
TOTAL (in.)	43.41	44.90	44.90	47.55	39.59	41.18	41.18	41.71		43.30	39.59	48.08					41.91
8001-9000(Ft. elev.)																	
D.A. (sq.mi.)	1.90	2.20			9.00	5.80		0.40									19.30
Rain Fall (in.)	42.06	44.22			40.62	40.31		42.16									41.11
Rain Absorbed (in.)	15.35	15.99			14.92	14.83		15.38									15.07
Snowmelt (in.)	1.59	1.61			1.57	1.57		1.59									1.58
TOTAL (in.)	28.30	29.84			27.27	27.05		28.37									27.62
9001-10000(Ft.elev.)																	
D.A. (sq.mi.)					1.80	0.10											1.90
Rain Fall (in.)					41.14	42.16											41.19
Rain Absorbed (in.)					41.14	42.16											41.19
Snowmelt (in.)					0.00	0.00											0.00
TOTAL (in.)					0.00	0.00											0.00
SUBBASIN TOTALS	2	3	4	6	9	120	15	16	17	21	22	23	24	25	27	281	BASIN TOTAL
D.A. (sq.mi.)	342.00	47.90	9.90	30.00	31.40	82.60	8.00	39.60	11.70	18.00	122.70	88.90	32.30	12.50	78.50	17.00	973.00
Rain Fall (in.)	36.10	42.94	43.62	39.07	39.22	39.26	40.11	39.72	38.69	39.00	35.63	37.27	32.26	30.23	28.99	22.47	36.27
Rain Absorbed (in.)	0.21	1.15	0.35	0.02	7.34	1.71	0.40	0.44	0.02	0.08	0.01	0.03	0.00	0.00	0.00	0.00	0.54
Snowmelt (in.)	2.30	4.00	4.11	4.08	2.20	3.22	3.54	4.25	4.42	4.20	2.94	3.22	1.41	0.20	0.28	0.00	2.59
TOTAL (in.)	38.19	45.79	47.38	43.13	34.08	40.78	43.25	43.53	43.09	43.11	38.56	40.46	33.68	30.43	29.27	22.47	38.32

Two two-foot high parapet walls were constructed, one at either end of the dam crest, to raise the crest of the dam between the spillway on the right abutment to left abutment to a minimum of 5,273 feet. If the dam does not fail, flood waters will overflow the embankment and the parapet wall for 25 hours and reach a maximum stage of 5,275.02 feet. Two scenarios were evaluated for this report, one without L. L. Anderson Dam failing and the other with it failing.

6. **RESULTS** - The results of this P.M.F. study consist of three parts: Excess precipitation for runoff, two hydrographs at the Auburn Dam site, and recommendations for the use of these hydrographs for sizing the dam's spillway.

The Storm Centering over the Auburn Dam basin produced the following basin average statistics.

- 72-hour Probable Maximum Precipitation	36.27 inches
- Snowmelt	2.59 inches
- Precipitation remaining in the snow	.54 inches
- Losses	7.19 inches
- Excess for runoff	38.32 inches

Two different inflow hydrographs to the Auburn Dam site were developed based on criteria presented in this report. One assumes no upstream dam failures, the second assumes L. L. Anderson Dam fails. These hydrographs are shown on Charts 71 and 72, and are tabulated on Tables 16 and 17 shown on pages 58 and 59. The Auburn Dam site P.M.F. summary is tabulated on Table 18, page 60.

TABLE K-16

NORTH FORK AMERICAN AT THE AUBURN DAM SITE
WITH NO UPSTREAM DAM FAILURES

DA MON HRMN	ORD	FLOW	DA MON HRMN	ORD	FLOW	DA MON HRMN	ORD	FLOW	DA MON HRMN	ORD	FLOW
1 JAN 0100	1	581.	2 JAN 0800	32	295226.	3 JAN 1500	63	178420.	4 JAN 2200	94	46398.
1 JAN 0200	2	911.	2 JAN 0900	33	313702.	3 JAN 1600	64	169425.	4 JAN 2300	95	44232.
1 JAN 0300	3	2704.	2 JAN 1000	34	332108.	3 JAN 1700	65	161430.	5 JAN 0000	96	42180.
1 JAN 0400	4	8418.	2 JAN 1100	35	349530.	3 JAN 1800	66	154166.	5 JAN 0100	97	40241.
1 JAN 0500	5	19324.	2 JAN 1200	36	365580.	3 JAN 1900	67	147511.	5 JAN 0200	98	38417.
1 JAN 0600	6	32163.	2 JAN 1300	37	380577.	3 JAN 2000	68	141390.	5 JAN 0300	99	36695.
1 JAN 0700	7	50752.	2 JAN 1400	38	394847.	3 JAN 2100	69	135796.	5 JAN 0400	100	35020.
1 JAN 0800	8	73644.	2 JAN 1500	39	408385.	3 JAN 2200	70	130725.	5 JAN 0500	101	33416.
1 JAN 0900	9	95672.	2 JAN 1600	40	421694.	3 JAN 2300	71	126142.	5 JAN 0600	102	31898.
1 JAN 1000	10	114005.	2 JAN 1700	41	436692.	4 JAN 0000	72	121915.	5 JAN 0700	103	30442.
1 JAN 1100	11	129348.	2 JAN 1800	42	455770.	4 JAN 0100	73	117881.	5 JAN 0800	104	29056.
1 JAN 1200	12	141793.	2 JAN 1900	43	481075.	4 JAN 0200	74	113892.	5 JAN 0900	105	27732.
1 JAN 1300	13	151863.	2 JAN 2000	44	514687.	4 JAN 0300	75	109831.	5 JAN 1000	106	26460.
1 JAN 1400	14	160329.	2 JAN 2100	45	550832.	4 JAN 0400	76	105667.	5 JAN 1100	107	25240.
1 JAN 1500	15	168319.	2 JAN 2200	46	574799.	4 JAN 0500	77	101333.	5 JAN 1200	108	24070.
1 JAN 1600	16	176891.	2 JAN 2300	47	576360.	4 JAN 0600	78	96983.	5 JAN 1300	109	22950.
1 JAN 1700	17	186687.	3 JAN 0000	48	557715.	4 JAN 0700	79	92754.	5 JAN 1400	110	21875.
1 JAN 1800	18	198202.	3 JAN 0100	49	528158.	4 JAN 0800	80	88645.	5 JAN 1500	111	20838.
1 JAN 1900	19	211307.	3 JAN 0200	50	494635.	4 JAN 0900	81	84668.	5 JAN 1600	112	19852.
1 JAN 2000	20	224836.	3 JAN 0300	51	460553.	4 JAN 1000	82	80828.	5 JAN 1700	113	18957.
1 JAN 2100	21	237245.	3 JAN 0400	52	426453.	4 JAN 1100	83	77164.	5 JAN 1800	114	18098.
1 JAN 2200	22	246945.	3 JAN 0500	53	392997.	4 JAN 1200	84	73711.	5 JAN 1900	115	17269.
1 JAN 2300	23	252786.	3 JAN 0600	54	358291.	4 JAN 1300	85	70482.	5 JAN 2000	116	16478.
2 JAN 0000	24	254518.	3 JAN 0700	55	325091.	4 JAN 1400	86	67498.	5 JAN 2100	117	15726.
2 JAN 0100	25	253077.	3 JAN 0800	56	295356.	4 JAN 1500	87	64531.	5 JAN 2200	118	15009.
2 JAN 0200	26	250350.	3 JAN 0900	57	269761.	4 JAN 1600	88	61634.	5 JAN 2300	119	14327.
2 JAN 0300	27	248610.	3 JAN 1000	58	248199.	4 JAN 1700	89	58835.	6 JAN 0000	120	13678.
2 JAN 0400	28	249835.	3 JAN 1100	59	229644.	4 JAN 1800	90	56138.	6 JAN 0100	121	13064.
2 JAN 0500	29	255150.	3 JAN 1200	60	214086.	4 JAN 1900	91	53546.			
2 JAN 0600	30	264752.	3 JAN 1300	61	200658.	4 JAN 2000	92	51057.			
2 JAN 0700	31	278316.	3 JAN 1400	62	188458.	4 JAN 2100	93	48674.			

PEAK FLOW	TIME		MAXIMUM AVERAGE FLOW			
			6-HR	24-HR	72-HR	120.00-HR
+ (CFS)	(HR)					
		(CFS)				
+ 576360.	46.00		548754.	433159.	265016.	173806.
		(INCHES)	5.254	16.590	30.450	33.283
		(AC-FT)	272110.	859159.	1576955.	1723696.

EFFECTIVE RUNOFF AREA = 971 SQ MI

TABLE K-17

NORTH FORK AMERICAN RIVER AT THE AUBURN DAM SITE
WITH THE FAILURE OF L .L. ANDERSON DAM (FRENCH MEADOWS RESERVOIR)

DA MON HRMN	ORD	FLOW	DA MON HRMN	ORD	FLOW	DA MON HRMN	ORD	FLOW	DA MON HRMN	ORD	FLOW
1 JAN 0100	1	581.	2 JAN 0800	32	295226.	3 JAN 1500	63	170767.	4 JAN 2200	94	40308.
1 JAN 0200	2	911.	2 JAN 0900	33	313702.	3 JAN 1600	64	161525.	4 JAN 2300	95	38297.
1 JAN 0300	3	2704.	2 JAN 1000	34	332108.	3 JAN 1700	65	153288.	5 JAN 0000	96	36385.
1 JAN 0400	4	8418.	2 JAN 1100	35	349530.	3 JAN 1800	66	145800.	5 JAN 0100	97	34573.
1 JAN 0500	5	19324.	2 JAN 1200	36	365580.	3 JAN 1900	67	138942.	5 JAN 0200	98	32851.
1 JAN 0600	6	32163.	2 JAN 1300	37	380577.	3 JAN 2000	68	132644.	5 JAN 0300	99	31212.
1 JAN 0700	7	50752.	2 JAN 1400	38	394847.	3 JAN 2100	69	126908.	5 JAN 0400	100	29650.
1 JAN 0800	8	73644.	2 JAN 1500	39	408385.	3 JAN 2200	70	121767.	5 JAN 0500	101	28166.
1 JAN 0900	9	95672.	2 JAN 1600	40	421694.	3 JAN 2300	71	117222.	5 JAN 0600	102	26766.
1 JAN 1000	10	114005.	2 JAN 1700	41	436692.	4 JAN 0000	72	113124.	5 JAN 0700	103	25426.
1 JAN 1100	11	129348.	2 JAN 1800	42	455778.	4 JAN 0100	73	109268.	5 JAN 0800	104	24153.
1 JAN 1200	12	141793.	2 JAN 1900	43	481290.	4 JAN 0200	74	105469.	5 JAN 0900	105	22941.
1 JAN 1300	13	151863.	2 JAN 2000	44	517559.	4 JAN 0300	75	101579.	5 JAN 1000	106	21781.
1 JAN 1400	14	160329.	2 JAN 2100	45	573264.	4 JAN 0400	76	97570.	5 JAN 1100	107	20671.
1 JAN 1500	15	168319.	2 JAN 2200	46	680172.	4 JAN 0500	77	93363.	5 JAN 1200	108	19611.
1 JAN 1600	16	176891.	2 JAN 2300	47	875485.	4 JAN 0600	78	89111.	5 JAN 1300	109	18601.
1 JAN 1700	17	186687.	3 JAN 0000	48	1068008.	4 JAN 0700	79	84959.	5 JAN 1400	110	17635.
1 JAN 1800	18	198202.	3 JAN 0100	49	1046466.	4 JAN 0800	80	80920.	5 JAN 1500	111	16705.
1 JAN 1900	19	211307.	3 JAN 0200	50	804097.	4 JAN 0900	81	77014.	5 JAN 1600	112	15825.
1 JAN 2000	20	224836.	3 JAN 0300	51	597599.	4 JAN 1000	82	73251.	5 JAN 1700	113	15031.
1 JAN 2100	21	237245.	3 JAN 0400	52	480494.	4 JAN 1100	83	69671.	5 JAN 1800	114	14267.
1 JAN 2200	22	246945.	3 JAN 0500	53	411442.	4 JAN 1200	84	66309.	5 JAN 1900	115	13527.
1 JAN 2300	23	252786.	3 JAN 0600	54	363487.	4 JAN 1300	85	63177.	5 JAN 2000	116	12820.
2 JAN 0000	24	254518.	3 JAN 0700	55	324201.	4 JAN 1400	86	60297.	5 JAN 2100	117	12149.
2 JAN 0100	25	253077.	3 JAN 0800	56	291628.	4 JAN 1500	87	57439.	5 JAN 2200	118	11513.
2 JAN 0200	26	250350.	3 JAN 0900	57	264259.	4 JAN 1600	88	54658.	5 JAN 2300	119	10911.
2 JAN 0300	27	248610.	3 JAN 1000	58	241825.	4 JAN 1700	89	51982.	6 JAN 0000	120	10342.
2 JAN 0400	28	249835.	3 JAN 1100	59	222903.	4 JAN 1800	90	49416.	6 JAN 0100	121	9806.
2 JAN 0500	29	255150.	3 JAN 1200	60	207149.	4 JAN 1900	91	46958.			
2 JAN 0600	30	264752.	3 JAN 1300	61	193498.	4 JAN 2000	92	44611.			
2 JAN 0700	31	278316.	3 JAN 1400	62	181054.	4 JAN 2100	93	42394.			

PEAK FLOW	TIME		MAXIMUM AVERAGE FLOW			
			6-HR	24-HR	72-HR	120.00-HR
+ (CFS)	(HR)					
		(CFS)				
+ 1068008.	47.00		843276.	515662.	289881.	186896.
		(INCHES)	8.074	19.749	33.307	35.790
		(AC-FT)	418154.	1022800.	1724911.	1853509.

EFFECTIVE RUNOFF AREA = 971 SQ MI

Table K-18

Auburn Dam Site P.M.F. Summary
Drainage Area 973 Sq. Mi.

Upstream Conditions	Peak Flow Tcfs	Peak Flow CSM	72-Hour Volume TAF	72-Hour Volume in.	120-Hour Volume TAF	120-Hour Volume in.
L. L. Anderson Dam Failure	1,068	1,100	1,725	33.3	1,854	35.8
No Upstream Dam Failures	576	594	1,577	30.5	1,724	33.3

Effective Runoff Area 971 sq. mi.

Definitions

in. = inches of water
Tcfs = thousands of cubic feet per second
CSM = cubic feet per second per sq. mi.
TAF = Thousands of acre feet of water

It is recommended that the hydrograph reflecting the L. L. Anderson Dam (French Meadows Reservoir) failure (Table 17, page 59, and Chart 72) be used to size the Auburn Dam spillway. It was assumed the failure of the dam occurred as the embankment was overtopped. A failure of this dam is included in the P.M.F. developed for Folsom Dam in the September 1980 Office Report, "American River Basin, California, Folsom Dam Spillway Adequacy Studies, Hydrology." The major differences between this routing and the 1980 Folsom P.M.F. routing is that for this study the spillway rating and storage elevation curves were revised for L. L. Anderson Dam to reflect the latest data from Placer County Water Agency. Chart 73 shows L. L. Anderson Dam Failure Routing. The second P.M.F. hydrograph, Table 16, page 58, and Chart 71, reflects no upstream dam failures.

7. SEDIMENT INFLOW -

A. GENERAL - When a reservoir is to be created, an allocated amount of the storage volume must be made for sediment deposition. For a reservoir, like the proposed Auburn Reservoir, knowledge of storage loss over time is important in determining how the reservoir is to function to meet its project purposes. The amount of sediment (in acre-feet per square mile per year) that can enter a reservoir over time, for reservoir and dam design, can be determined by knowing the sediment yield of a basin. The following discussion explains how the sediment yield for the Auburn Dam drainage basin was developed.

B. **ORIGINAL STUDY** - The Bureau of Reclamation (USBR) in September 1967 conducted a detailed sediment study for the Auburn Dam. This study consisted of taking periodic suspended sediment samples at the Middle Fork American River near Auburn stream gage from 1958 through 1965. A suspended sediment rating curve and a flow duration curve were developed for this gaging station. Complete particle size analyses were made by the USGS on four suspended sediment samples. Table 19, shows the weighted average of these samples.

TABLE K-19

AUBURN DAM SITE
PERCENT SEDIMENT BY WEIGHT

TYPE	PERCENT
Clay	16.8
Silt	65.9
Sand	17.3

The USBR estimated that the 100 year unit weight of the deposited sediment would be 77 pounds per cubic foot.

The USGS did not take any bedload samples from the American River. A value of 25 percent of suspended load was used for the estimated bedload based upon observations of the channel and earlier Auburn sediment studies. This USBR study estimated the total sediment yield rate to be 0.27 acre feet per square mile per year. This estimate was based on the available data collected and using the flow duration - sediment rating curve method.

C. **PRESENT EVALUATION** - A review of three reports on sediment and reservoir sediment survey sheets was made to determine how the USBR yield value of 0.27 acre feet/sq.mi./year compared with similar drainage basins. This review showed that the USBR sediment yield value of 0.27 acre feet/sq. mi./year is very reasonable and therefore will be used for estimating the 100 year deposition at the Auburn Dam site.

Table 20, page 60, shows published sediment yield rates for reservoirs whose drainage basin characteristics are similar to the American River basin.

TABLE K-20

SEDIMENT YIELD RATES

Basin	Drainage Area (sq. mi)	Sediment Yield (AF/sq.mi./yr)
Oroville Reservoir	3611	0.2
Bullards Bar Reservoir	487	0.28
Combie Reservoir	130	0.75
New Melones Reservoir	904	0.13
Pine Flat Reservoir	1542	0.16
Don Pedro Reservoir	1001	0.21
Exchequer Reservoir	1027	0.18
Pardee Reservoir	387	0.15

The three reports on sediment that were reviewed are as follows:

(1) The tables and chart in the report "Factors Affecting Sediment Yield in the Pacific Southwest", dated April 1968, were used to estimate a yield for the American River basin above Auburn Dam site. An analysis of the chart and the tables showed the basin to have a classification of 4. This indicates that the sediment yield should be in the range of 0.2 to 0.5 AF/sq.mi.; this complements the USBR value of 0.27.

(2) Table CA-2, (Suspended Sediment and Salt Load Discharge), and Table CA-3, (Summary of Reservoir sedimentation surveys by region and subregion for the State of California), in the US Dept. of Agriculture report, "Erosion, Sediment and Related Salt Problems and Treatment Opportunities", dated December 1975, show that the 0.27 yield value is reasonable, if not on the high side.

(3) Reservoir Sedimentation Data Summary sheets from the Water Resources Council Sedimentation Committee's "Supplement to Sediment Deposition in U.S. Reservoirs ", dated July 1975, show the 0.27 value to be reasonable.

The Auburn Dam drainage basin is 971 square miles and has several dams within the basin. The uncontrolled area below these dams is 449 square miles. The 100-year deposition is estimated to range from 12,100 acre feet (449 sq. mi.) to 26,200 acre feet (971 sq. mi.), using the 0.27 yield value. The deposition of 12,100 acre feet assumes the upstream dams have a trap efficiency of 100 percent. Auburn Dam is expected to have a capacity of 600,000 acre feet (to provide a 200-year level of protection). Assuming that 26,200 acre feet of sediment occurs (during the next 100 years), this would amount to about 4% of the reservoir capacity, which will have a minimum impact on the capacity of the proposed reservoir.

8. **WIND-WAVE RUNUP** -

A. **Fetch Lengths** - Two fetch lengths were used. The first was a north fetch of approximately 2000 feet. The second was a northeast fetch of approximately 7000 feet in length. These fetch lengths are shown on Chart 74.

B. **Wind Analysis** - Wind data from the Sacramento Executive Airport was used to compute the design windspeed. This station is some distance from the Auburn Dam site, but was the only data available. Analysis of the Executive Airport data shows northeast winds to be very rare. Therefore, the north wind was used for the northeast fetch to estimate the possible wind effects.

C. **Pool Elevation** - The max pool elevation for the 200-year flood of 924 ft msl was used to compute the water depths for the wave analyses.

D. **Results** - Table 21 lists pertinent information. Wave runup calculations are based on a vertical dam face.

TABLE K-21

AUBURN DAM SITE
WIND-WAVE ANALYSIS RESULTS

Wind Direction	Design Wind Speed (mph)	Wind Duration (min)	Design Wave (ft)	Wind Set (ft)	Wave Runup (ft)	Water Depth (ft)	Fetch Length (ft)
North	48	9	1.3	0.0	.05	400	2000
Northeast	49	22	2.5	.01	0.0	400	7000

TABLE K-22 PAGE 1 OF 5

AMERICAN RIVER AND SACRAMENTO METRO INVESTIGATIONS
F L O W S   A N D   S T A G E S
PREPROJECT CONDITIONS (WITH FREEBOARD FAILURES)
FREMONT SEDIMENT ELEVATION @ 31.0

		SACRAMENTO RIVER SYSTEM										AMER RIVER	NEMOC	CROSS CANAL	YOLO BYPASS						SAC BYPAS						
COMMENT	FILENAME	FREMONT WEIR STAGE ft msl	FREMONT WEIR FLOW cfs	VERONA STAGE ft msl	VERONA FLOW cfs	SAC WEIR STAGE ft msl	SAC WEIR FLOW cfs	I-ST STAGE ft msl	I-ST FLOW cfs	FREEPORT STAGE ft msl	FREEPORT FLOW cfs	H-STREET STAGE ft msl	MAIN AVE STAGE ft msl	HIWAY 99 ft msl	FILENAME	RIDGE CUT ft msl	WOODLND ft msl	D/S SAC BYPAS ft msl	SHIP CHANL ft msl	LISBN ft msl	MILE 1 ft msl	FAILURE LOCATIONS A	B	C	D	E	F
1986 OBSERVED		38.54	341000	39.11	92900	30.56	128000	30.58		25.11	117000	40.4	35.6	39.6		34	31.4	29.2	27.5	24.9	29.5est						
1986 COMPUTED FREMONT @ 32.0	DMET863	38.9	341000	39.2	92900	30.3	124000	30.6	113000	24.9	113000	40.9	35.7	39.3	DY0863	33.9	31.5	29	27.3	24.9	29.7						
100 YR ON SAC 100 YR ON AMER	DME3108	38.1	358000	38.2	117000	31.4	144000	32.5	123000	27	120000	41.7	36.9	39	DY03108	34.4	31.8	29.4	27.8	25.3	30.2	X	X	X		X	X
100 YR ON SAC 100 YR ON AMER	DME310B1	38.5	386000	38.8	90000	31.7	153000	32.7	126000	27.4	122000	41.7	36.9	39.6	DY0310B1	35.1	32.4	30	28.2	25.6	30.8	X	X	X			X
200 YR ON SAC 100 YR ON AMER	DME320B	38.4	384000	38.5	136000	31.5	146000	32.7	123000	27.3	121000	41.7	36.9	39.1	DY0320B	35	32.3	29.8	28.1	25.5	30.6	X	X	X		X	X
200 YR ON SAC 100 YR ON AMER	DME320B1	39	426000	39.6	95000	32	158000	33.1	126000	27.7	124000	41.7	36.9	40.1	DY0320B1	35.9	33	30.5	28.7	25.9	31.3	X	X	X			X
400 YR ON SAC 100 YR ON AMER	DME340B	38.6	394000	38.6	140000	31.6	147000	32.7	123000	27.3	122000	41.7	36.9	39.3	DY340B	35.2	32.5	30	28.3	25.6	30.8	X	X	X		X	X
400 YR ON SAC 100 YR ON AMER	DME340B1	39.1	438000	39.8	96000	32.1	160000	33.2	126000	27.8	124000	41.7	36.9	40.3	DY340B1	36.1	33.3	30.8	28.9	26	31.6	X	X	X			X
100YR ON SAC 200 YR ON AMER	DME3200	38.1	358000	38.3	120000	33.3	179000	35.8	143000	30.3	140000	43	38.1	39	DY03200	34.6	32.1	29.9	28.2	25.6	31.1	X	X	X	X	X	X
100 YR ON SAC 200 YR ON AMER	DME32001	38.6	393000	39.3	91000	33.8	194000	36.2	146000	30.6	142000	43	38.1	39.8	DY032001	35.4	32.8	30.6	28.8	25.9	31.8	X	X	X	X		X
100 YR ON SAC 400 YR ON AMER	DME340F	38.1	359000	38.3	117000	34	191000	36.9	149000	31.3	147000	43.2	38.2	39	DY0340F	34.6	32.3	30.2	28.4	25.7	31.4	X	X	X	X	X	X
100 YR ON SAC 400 YR ON AMER	DME340F1	38.6	398000	39.3	92000	34.6	208000	37.3	150000	31.7	150000	43.2	38.2	39.8	DY0340F1	35.5	33	30.9	29	26.1	32.2	X	X	X	X		X

------LEVEE FAILURE LOCATIONS------
A. RIGHT BANK AMERICAN RIVER ABOVE H-STREET
B. LEFT BANK AMERICAN RIVER MAYHEW DRAIN AREA
C. RIGHT BANK FLOW RETURN TO AMERICAN RIVER
D. RIGHT BANK AMERICAN RIVER BELOW NEMDC
E. RIGHT BANK SAC RIVER (AREA C)
F. WEST LEVEE NATOMAS EAST MAIN DRAIN

----- COMPUTATIONAL POINT LOCATIONS -----
FREMONT WEIR - FREMONT WEIR WEST END (LOCATION 37 ON CHART 1).
VERONA - SACRAMENTO RIVER AT VERONA (LOCATION 34 ON CHART 1).
SAC WEIR - SACRAMENTO RIVER AT NORTH END OF THE SAC WEIR.
I-STREET - SACRAMENTO RIVER AT I-STREET (LOCATION 46 ON CHART 1).
FREEPORT - SACRAMENTO RIVER AT FREEPORT (LOCATION 47 ON CHART 1).
H-STREET - AMERICAN RIVER AT H-STREET (LOCATION 45 ON CHART 1).
MAIN AVE - NEMDC JUST DOWNSTREAM OF DRY CREEK
HIWAY 99 - CROSS CANAL AT HIGHWAY 99 CROSSING
RIDGE CUT - YOLO BYPASS AT KNIGHTS LANDING RIDGE CUT (NEAR LOCATION 39 ON CHART 1)
WOODLAND - YOLO BYPASS AT WOODLAND (LOCATION 40 ON CHART 1).
D/S SAC BYPASS - YOLO BYPASS JUST DOWNSTREAM OF THE SACRAMENTO BYPASS
SHIP CHANNEL - YOLO BYPASS APPROXIMATELY 1 MILE DOWNSTREAM OF INTERSTATE 80.
LISBON - YOLO BYPASS AT LISBON (LOCATION 49 ON CHART 1).
SAC BYPASS - MIDPOINT BETWEEN SAC WEIR AND YOLO BYPASS

FILE SAC1
JH 2/15/90

A1-T65
U1-A265

TABLE K-22 PAGE 2 OF 5

AMERICAN RIVER AND SACRAMENTO METRO INVESTIGATIONS
F L O W S   A N D   S T A G E S
PREPROJECT CONDITIONS (WITH FREEBOARD FAILURES)
FREMONT SEDIMENT ELEVATION @ 32.0

		SACRAMENTO RIVER SYSTEM										AMER RIVER	NEMDC	CROSS CANAL	YOLO BYPASS						SAC BYPAS						
COMMENT	FILENAME	FREMONT WEIR STAGE ft msl	FREMONT WEIR FLOW cfs	VERONA STAGE ft msl	VERONA FLOW cfs	SAC WEIR STAGE ft msl	SAC WEIR FLOW cfs	I-ST STAGE ft msl	I-ST FLOW cfs	FREEPORT STAGE ft msl	FREEPORT FLOW cfs	H-STREET STAGE ft msl	MAIN AVE STAGE ft msl	HIWAY 99 ft msl	FILENAME	RIDGE CUT ft msl	WOODLND ft msl	D/S SAC BYPAS ft msl	SHIP CHANL ft msl	LISBN ft msl	MILE 1 ft msl	FAILURE LOCATIONS A	B	C	D	E	F
1986 OBSERVED		38.54	341000	39.11	92900	30.56	128000	30.58		25.11	117000	40.4	35.6	39.6		34	31.4	29.2	27.5	24.9	29.5est						
1986 COMPUTED FREMONT @ 32.0	DMET863	38.9	341000	39.2	92900	30.3	124000	30.6	113000	24.9	113000	40.9	35.7	39.3	DY0863	33.9	31.5	29	27.3	24.9	29.7						
100 YR ON SAC 100 YR ON AMER	DME310C	38.8	336000	38.6	139000	31.4	144000	32.5	125000	27.1	120000	41.7	36.9	39.3	DY0310C	33.9	31.4	29	27.4	25.1	29.8	X	X	X		X	X
100 YR ON SAC 100 YR ON AMER	DME310C1	39.4	380000	39.8	95000	31.1	157000	33	127000	27.6	123000	41.7	36.9	40.4	DY0310C1	34.9	32.3	29.9	28.2	25.6	30.8	X	X	X			X
200 YR ON SAC 100 YR ON AMER	DME320C	39.3	373000	39.2	145000	31.7	149000	32.8	124000	27.4	122000	41.7	36.9	39.7	DY0320C	34.8	32.1	29.7	28	25.5	30.5	X	X	X		X	X
200 YR ON SAC 100 YR ON AMER	DME320C1	39.9	418000	40.4	102000	32.2	163000	33.3	127000	27.9	125000	41.7	36.9	40.8	DY0320C1	35.7	33	30.5	28.7	25.9	31.3	X	X	X			X
400 YR ON SAC 100 YR ON AMER	DME340C	39.4	379000	39.3	154000	31.7	149000	32.8	125000	27.4	122000	41.7	36.9	39.8	DY0340C	34.9	32.2	29.8	28.1	25.5	30.6	X	X	X		X	X
400 YR ON SAC 100 YR ON AMER	DME340C1	40	430000	40.6	103000	32.3	165000	33.4	128000	28	125000	41.7	36.9	41.1	DY0340C1	36	33.2	30.7	28.9	26	31.6	X	X	X			X
100 YR ON SAC 200 YR ON AMER	DME320E	39	347000	38.9	128000	33.5	183000	35.9	143000	30.3	140000	43	38.1	39.6	DY0320E	34.4	32	29.8	28.1	25.5	31	X	X	X	X	X	X
100 YR ON SAC 200 YR ON AMER	DME320E1	39.5	388000	40	95000	34	200000	36.3	147000	30.7	143000	43	38.1	40.5	DY0320E1	35.3	32.8	30.6	28.7	25.9	31.8	X	X	X	X		X
100 YR ON SAC 400 YR ON AMER	DME3406	39	349000	30	126000	34.1	196000	37	149000	31.4	148000	43.2	38.2	39.6	DY03406	34.5	32.1	30.1	28.3	25.6	31.4	X	X	X	X	X	X
100 YR ON SAC 400 YR ON AMER	DME34061	39.5	390000	40.1	100000	34.7	214000	37.5	152000	31.8	151000	43.2	38.2	40.5	DY034061	35.4	32.9	30.8	28.9	26	32.2	X	X	X	X		X

------LEVEE FAILURE LOCATIONS------
A. RIGHT BANK AMERICAN RIVER ABOVE H-STREET
B. LEFT BANK AMERICAN RIVER MAYHEW DRAIN AREA
C. RIGHT BANK FLOW RETURN TO AMERICAN RIVER
D. RIGHT BANK AMERICAN RIVER BELOW NEMDC
E. RIGHT BANK SAC RIVER (AREA C)
F. WEST LEVEE NATOMAS EAST MAIN DRAIN

----- COMPUTATIONAL POINT LOCATIONS -----
FREMONT WEIR - FREMONT WEIR WEST END (LOCATION 37 ON CHART 1).
VERONA - SACRAMENTO RIVER AT VERONA (LOCATION 34 ON CHART 1).
SAC WEIR - SACRAMENTO RIVER AT NORTH END OF THE SAC WEIR.
I-STREET - SACRAMENTO RIVER AT I-STREET (LOCATION 46 ON CHART 1).
FREEPORT - SACRAMENTO RIVER AT FREEPORT (LOCATION 47 ON CHART 1).
H-STREET - AMERICAN RIVER AT H-STREET (LOCATION 45 ON CHART 1).
MAIN AVE - NEMDC JUST DOWNSTREAM OF DRY CREEK
CROSS CANAL - CROSS CANAL AT HIGHWAY 99 CROSSING
RIDGE CUT - YOLO BYPASS AT KNIGHTS LANDING RIDGE CUT (NEAR LOCATION 39 ON CHART 1)
WOODLAND - YOLO BYPASS AT WOODLAND (LOCATION 40 ON CHART 1).
D/S SAC BYPASS - YOLO BYPASS JUST DOWNSTREAM OF THE SACRAMENTO BYPASS
SHIP CHANNEL - YOLO BYPASS APPROXIMATELY 1 MILE DOWNSTREAM OF INTERSTATE 80.
LISBON - YOLO BYPASS AT LISBON (LOCATION 49 ON CHART 1).
SAC BYPASS - MIDPOINT BETWEEN SAC WEIR AND YOLO BYPASS

FILE SACS
JH 2/15/90

A1-T65
U1-R265

TABLE K-22 PAGE 3 OF 5

AMERICAN RIVER AND SACRAMENTO METRO INVESTIGATIONS
F L O W S   A N D   S T A G E S
PROJECT FLOWS ON AMERICAN RIVER (FREEBOARD FAILURES)
FREMONT SEDIMENT ELEVATION @ 31.0

COMMENT	FILENAME	SACRAMENTO RIVER SYSTEM: FREMONT WEIR STAGE ft msl	FREMONT WEIR FLOW cfs	VERONA STAGE ft msl	VERONA FLOW cfs	SAC WEIR STAGE ft msl	SAC WEIR FLOW cfs	I-ST STAGE ft msl	I-ST FLOW cfs	FREEPORT STAGE ft msl	FREEPORT FLOW cfs	AMER RIVER: H-STREET STAGE ft msl	NEMDC: MAIN AVE STAGE ft msl	CROSS CANAL: HIWAY 99 ft msl	FILENAME	YOLO BYPASS: RIDGE CUT ft msl	WOODLND ft msl	D/S SAC BYPAS ft msl	SHIP CHANL ft msl	LISBN ft msl	SAC BYPAS: MILE 1 ft msl	FAILURE LOCATIONS A	B	C	D	E	F
100 YR ON SAC 115K ON AMER	DME510B	38.1	355000	38.2	120000	29.4	107000	29.6	106000	24.3	105000	39.2	35.3	39	DY0510B	34.2	31.5	29	27.4	25.1	29.5					X	
200 YR ON SAC 115K ON AMER	DME520B	38.4	381000	38.4	140000	29.4	107000	29.6	106000	24.3	105000	39.2	35.3	39.1	DY0520B	34.7	32	29.3	27.7	25.3	29.8					X	
400 YR ON SAC 115K ON AMER	DME540B	38.5	391000	38.5	140000	29.4	107000	29.6	106000	24.3	105000	39.2	35.3	39.3	DY0540B	35	32.1	29.5	27.8	25.3	30					X	
100 YR ON SAC 130K ON AMER	DME610B	38.1	355000	38.2	120000	30	117000	30.4	110000	25	109000	40.5	35.8	39	DY0610B	34.2	31.6	29.1	27.6	25.2	29.7					X	
200 YR ON SAC 130K ON AMER	DME620B	38.4	381000	38.4	138000	30	117000	30.4	110000	25	109000	40.5	35.8	39.1	DY0620B	34.8	32	29.5	27.8	25.3	30					X	
400 YR ON SAC 130K ON AMER	DME640B	38.5	391000	38.6	141000	30	117000	30.4	110000	25	109000	40.5	35.8	39.3	DY0640B	35	32.2	29.6	27.9	25.4	30.2					X	
100 YR ON SAC 180K ON AMER	DME710C	38.1	358000	38.3	121000	31.6	147000	32.8	123000	27.4	121000	41.2	36.5	39	DY0710C	34.4	31.9	29.5	27.9	25.4	30.4	X	X	X		X	X
200 YR ON SAC 180K ON AMER	DME720C	38.4	383000	38.5	136000	31.6	147000	32.8	123000	27.4	121000	41.2	36.5	39.1	DY0720C	35	32.3	29.9	28.2	25.6	30.7	X	X	X		X	X
400 YR ON SAC 180K ON AMER	DME740C	38.6	393000	38.6	138000	31.6	147000	32.8	123000	27.5	122000	41.2	36.5	39.3	DY0740C	35.2	32.5	30.1	28.3	25.7	30.9	X	X	X		X	X

------LEVEE FAILURE LOCATIONS------
A. RIGHT BANK AMERICAN RIVER ABOVE H-STREET
B. LEFT BANK AMERICAN RIVER MAYHEW DRAIN AREA
C. RIGHT BANK FLOW RETURN TO AMERICAN RIVER
D. RIGHT BANK AMERICAN RIVER BELOW NEMDC
E. RIGHT BANK SAC RIVER (AREA C)
F. WEST LEVEE NATOMAS EAST MAIN DRAIN

----- COMPUTATIONAL POINT LOCATIONS -----
FREMONT WEIR - FREMONT WEIR WEST END (LOCATION 37 ON CHART 1).
VERONA - SACRAMENTO RIVER AT VERONA (LOCATION 34 ON CHART 1).
SAC WEIR - SACRAMENTO RIVER AT NORTH END OF THE SAC WEIR.
I-STREET - SACRAMENTO RIVER AT I-STREET (LOCATION 46 ON CHART 1).
FREEPORT - SACRAMENTO RIVER AT FREEPORT (LOCATION 47 ON CHART 1).
H-STREET - AMERICAN RIVER AT H-STREET (LOCATION 45 ON CHART 1).
MAIN AVE - NEMDC JUST DOWNSTREAM OF DRY CREEK
HIWAY 99 - CROSS CANAL AT HIGHWAY 99 CROSSING
RIDGE CUT - YOLO BYPASS AT KNIGHTS LANDING RIDGE CUT (NEAR LOCATION 39 ON CHART 1)
WOODLAND - YOLO BYPASS AT WOODLAND (LOCATION 40 ON CHART 1).
D/S SAC BYPASS - YOLO BYPASS JUST DOWNSTREAM OF THE SACRAMENTO BYPASS
SHIP CHANNEL - YOLO BYPASS APPROXIMATELY 1 MILE DOWNSTREAM OF INTERSTATE 80.
LISBON - YOLO BYPASS AT LISBON (LOCATION 49 ON CHART 1).
SAC BYPASS - MIDPOINT BETWEEN SAC WEIR AND YOLO BYPASS

FILE SAC3
JH 2/15/90

A1-I58
U1-AZ58

TABLE K-22 PAGE 4 OF 5

AMERICAN RIVER AND SACRAMENTO METRO INVESTIGATIONS
F L O W S A N D S T A G E S
PROJECT CONDITIONS
NO FAILURES
FREMONT SEDIMENT ELEVATION @ 31.0

		SACRAMENTO RIVER SYSTEM										AMER RIVER	NEMDC	CROSS CANAL		YOLO BYPASS					SAC BYPAS					
COMMENT	FILENAME	FREMONT WEIR STAGE ft msl	FREMONT WEIR FLOW cfs	VERONA STAGE ft msl	VERONA FLOW cfs	SAC WEIR STAGE ft msl	SAC WEIR FLOW cfs	I-ST STAGE ft msl	I-ST FLOW cfs	FREEPORT STAGE ft msl	FREEPORT FLOW cfs	H-STREET STAGE ft msl	MAIN AVE STAGE ft msl	HIWAY 99 ft msl	FILENAME	RIDGE CUT ft msl	WOODLND ft msl	D/S SAC BYPAS ft msl	SHIP CHANL ft msl	LISBN ft msl	MILE 1 ft msl	FAILURE LOCATIONS A	B	C	D	E
100 YR ON SAC 115K ON AMER	DME510B1	38.4	383000	38.9	92000	29.8	115000	30	107000	24.7	107000	39.2	35.3	39.6	DY0510B1	34.8	32.1	29.5	27.8	25.3	30					
200 YR ON SAC 115K ON AMER	DME520B1	38.9	421000	39.6	97000	29.9	118000	30.2	108000	24.8	108000	39.2	35.3	40	DY0520B1	35.6	32.7	30	28.3	25.6	30.6					
400 YR ON SAC 115K ON AMER	DME540B1	39	433000	39.7	97000	30	119000	30.2	109000	24.8	108000	39.2	35.3	40.2	DY0540B1	35.9	32.9	30.2	28.5	25.7	30.8					
100 YR ON SAC 130K ON AMER	DME610B1	38.4	383000	39	92000	30.3	125000	30.7	112000	25.4	111000	40.5	35.8	39.6	DY0610B1	34.9	32.1	29.6	27.9	25.4	30.3					
200 YR ON SAC 130K ON AMER	DME620B1	38.9	422000	39.6	96000	30.4	128000	30.9	112000	25.5	112000	40.5	35.8	40	DY0620B1	35.7	32.8	30.2	28.4	25.7	30.8					
400 YR ON SAC 130K ON AMER	DME640B1	39	433000	39.8	97000	30.5	130000	31	112000	25.6	112000	40.5	35.8	40.2	DY0640B1	35.9	33	30.4	28.6	25.8	31					
100 YR ON SAC 180K ON AMER	DME710C1	38.5	387000	39.1	89000	32	157000	33.1	124000	27.8	123000	44	37.7	39.6	DY0710C1	35.1	32.5	30.1	28.4	25.7	31					
200 YR ON SAC 180K ON AMER	DME720C1	38.9	426000	39.7	91000	32.1	160000	33.3	125000	27.9	124000	44	37.7	40.1	DY0720C1	35.8	33.1	30.6	28.8	25.9	31.5					
400 YR ON SAC 180K ON AMER	DME740C1	39.1	438000	39.9	94000	32.1	162000	33.3	125000	27.9	124000	44	37.7	40.3	DY0740C1	36.1	33.3	30.8	29	26	31.7					

------*LEVEE FAILURE LOCATIONS*------
A. RIGHT BANK AMERICAN RIVER ABOVE H-STREET
B. LEFT BANK AMERICAN RIVER MAYHEW DRAIN AREA
C. RIGHT BANK FLOW RETURN TO AMERICAN RIVER
D. RIGHT BANK AMERICAN RIVER BELOW NEMDC
E. RIGHT BANK SAC RIVER (AREA C)
F. WEST LEVEE NATOMAS EAST MAIN DRAIN

----- *COMPUTATIONAL POINT LOCATIONS* -----
FREMONT WEIR - FREMONT WEIR WEST END (LOCATION 37 ON CHART 1).
VERONA - SACRAMENTO RIVER AT VERONA (LOCATION 34 ON CHART 1).
SAC WEIR - SACRAMENTO RIVER AT NORTH END OF THE SAC WEIR.
I-STREET - SACRAMENTO RIVER AT I-STREET (LOCATION 46 ON CHART 1).
FREEPORT - SACRAMENTO RIVER AT FREEPORT (LOCATION 47 ON CHART 1).
H-STREET - AMERICAN RIVER AT H-STREET (LOCATION 45 ON CHART 1).
MAIN AVE - NEMDC JUST DOWNSTREAM OF DRY CREEK
HIWAY 99 - CROSS CANAL AT HIGHWAY 99 CROSSING
RIDGE CUT - YOLO BYPASS AT KNIGHTS LANDING RIDGE CUT (NEAR LOCATION 39 ON CHART 1)
WOODLAND - YOLO BYPASS AT WOODLAND (LOCATION 40 ON CHART 1).
D/S SAC BYPASS - YOLO BYPASS JUST DOWNSTREAM OF THE SACRAMENTO BYPASS
SHIP CHANNEL - YOLO BYPASS APPROXIMATELY 1 MILE DOWNSTREAM OF INTERSTATE 80.
LISBON - YOLO BYPASS AT LISBON (LOCATION 49 ON CHART 1).
SAC BYPASS - MIDPOINT BETWEEN SAC WEIR AND YOLO BYPASS

FILE SAC4
JH 2/15/90

A1-IS8
U1-AXS8

TABLE K-22 PAGE 5 OF 5

AMERICAN RIVER AND SACRAMENTO METRO INVESTIGATIONS
F L O W S   A N D   S T A G E S
PREPROJECT CONDITIONS (WITH FREEBOARD FAILURES)
FREMONT SEDIMENT ELEVATION @ 30.5

		SACRAMENTO RIVER SYSTEM										AMER RIVER	NEMDC	CROSS CANAL		YOLO BYPASS					SAC BYPAS	FAILURE LOCATIONS						
COMMENT	FILENAME	FREMONT WEIR STAGE ft msl	FREMONT WEIR FLOW cfs	VERONA STAGE ft msl	VERONA FLOW cfs	SAC WEIR STAGE ft msl	SAC WEIR FLOW cfs	I-ST STAGE ft msl	I-ST FLOW cfs	FREEPORT STAGE ft msl	FREEPORT FLOW cfs	H-STREET STAGE ft msl	MAIN AVE STAGE ft msl	HIWAY 99 ft msl	FILENAME	RIDGE CUT ft msl	WOODLND ft msl	D/S SAC BYPAS ft msl	SHIP CHANL ft msl	LISBN ft msl	MILE 1 ft msl	A	B	C	D	E	F	G
100 YR ON SAC 100 YR ON AMER WITH CROSS CANAL FAILURE	DXE7100	38	390000	38.7	87000	31.6	150000	32.7	126000	27.3	121000	41.7	36.9	39.3	DYX7100	35.1	32.4	29.9	28.2	25.6	30.7	X	X	X			X	
200 YR ON SAC 100 YR ON AMER WITH CROSS CANAL FAILURE	DXE7200	38.2	409000	38.9	115000	31.9	154000	33	128000	27.6	123000	41.7	36.9	39.4	DYX7200	35.5	32.8	30.3	28.5	25.8	31.1	X	X	X			X	X
400 YR ON SAC 100 YR ON AMER WITH CROSS CANAL FAILURE	DXE7400	38.4	419000	38.9	117000	31.9	156000	33	128000	27.6	123000	41.7	36.9	39.5	DYX7400	35.7	33	30.4	28.6	25.8	31.3	X	X	X			X	X

------LEVEE FAILURE LOCATIONS------
A. RIGHT BANK AMERICAN RIVER ABOVE H-STREET
B. LEFT BANK AMERICAN RIVER MAYHEW DRAIN AREA
C. RIGHT BANK FLOW RETURN TO AMERICAN RIVER
D. RIGHT BANK AMERICAN RIVER BELOW NEMDC
E. RIGHT BANK SAC RIVER (AREA C)
F. WEST LEVEE NATOMAS EAST MAIN DRAIN
G. SOUTH LEVEE CROSS CANAL

----- COMPUTATIONAL POINT LOCATIONS -----
FREMONT WEIR - FREMONT WEIR WEST END (LOCATION 37 ON CHART 1).
VERONA - SACRAMENTO RIVER AT VERONA (LOCATION 34 ON CHART 1).
SAC WEIR - SACRAMENTO RIVER AT NORTH END OF THE SAC WEIR.
I-STREET - SACRAMENTO RIVER AT I-STREET (LOCATION 46 ON CHART 1).
FREEPORT - SACRAMENTO RIVER AT FREEPORT (LOCATION 47 ON CHART 1).
H-STREET - AMERICAN RIVER AT H-STREET (LOCATION 45 ON CHART 1).
MAIN AVE - NEMDC JUST DOWNSTREAM OF DRY CREEK
HIWAY 99 - CROSS CANAL AT HIGHWAY 99 CROSSING
RIDGE CUT - YOLO BYPASS AT KNIGHTS LANDING RIDGE CUT (NEAR LOCATION 39 ON CHART 1)
WOODLAND - YOLO BYPASS AT WOODLAND (LOCATION 40 ON CHART 1).
D/S SAC BYPASS - YOLO BYPASS JUST DOWNSTREAM OF THE SACRAMENTO BYPASS
SHIP CHANNEL - YOLO BYPASS APPROXIMATELY 1 MILE DOWNSTREAM OF INTERSTATE 80.I
LISBON - YOLO BYPASS AT LISBON (LOCATION 50 ON CHART 1).
SAC BYPASS - MIDPOINT BETWEEN SAC WEIR AND YOLO BYPASS

FILE SAC19
JH 6/29/90

A1-T40
U1-BB40

TABLE K-23

AMERICAN RIVER AND SACRAMENTO METRO INVESTIGATIONS
F L O W S   A N D   S T A G E S
PROJECT CONDITIONS
NO FAILURES

FREMONT SEDIMENT ELEVATION @ 31.0 AT EXISTING WIDTH

		SACRAMENTO RIVER SYSTEM										AMER RIVER	NEMDC	CROSS CANAL		YOLO BYPASS					SAC BYPAS						
COMMENT	FILENAME	FREMONT WEIR STAGE ft msl	FREMONT WEIR FLOW cfs	VERONA STAGE ft msl	VERONA FLOW cfs	SAC WEIR STAGE ft msl	SAC WEIR FLOW cfs	I-ST STAGE ft msl	I-ST FLOW cfs	FREEPORT STAGE ft msl	FREEPORT FLOW cfs	H-STREET STAGE ft msl	MAIN AVE STAGE ft msl	HIWAY 99 ft msl	FILENAME	RIDGE CUT ft msl	WOODLND ft msl	D/S SAC BYPAS ft msl	SHIP CHANL ft msl	LISBN ft msl	MILE 1 ft msl	FAILURE LOCATIONS A	B	C	D	E	F
100 YR ON SAC 115K ON AMER	DME510B1	38.4	383000	38.9	92000	29.8	115000	30	107000	24.7	107000	39.2	35.3	39.6	DYO510B1	34.8	32.1	29.5	27.8	25.3	30						
200 YR ON SAC 115K ON AMER	DME520B1	38.9	421000	39.6	97000	29.9	118000	30.2	108000	24.8	108000	39.2	35.3	40	DYO520B1	35.6	32.7	30	28.3	25.6	30.6						
400 YR ON SAC 115K ON AMER	DME540B1	39	433000	39.7	97000	30	119000	30.2	109000	24.8	108000	39.2	35.3	40.2	DYO540B1	35.9	32.9	30.2	28.5	25.7	30.8						

FREMONT SEDIMENT ELEVATION @ 30.5 AT EXISTING WIDTH

100 YR ON SAC 115K ON AMER	DME510H1	37.9	386000	38.7	89000	29.7	113000	29.9	107000	24.6	107000	39.2	35.3	39.2	DYO510H1	34.9	32.1	29.5	27.8	25.3	30						
200 YR ON SAC 115K ON AMER	DME520H1	38.4	424000	39.2	94000	29.8	116000	30	108000	24.7	108000	39.2	35.3	39.6	DYO520H1	35.6	32.7	30	28.3	25.6	30.6						
400 YR ON SAC 115K ON AMER	DME540H1	38.6	436000	39.3	94000	29.9	117000	30	108000	24.7	108000	39.2	35.3	39.9	DYO540H1	35.9	33	30.2	28.5	25.7	30.8						

FREMONT SEDIMENT ELEVATION @ 30.5 WITH WEIR WIDENED 1000 FEET

100 YR ON SAC 115K ON AMER	DFRE10J	37.4	389000	38.1	86000	29.6	110000	29.8	106000	24.5	106000	39.2	35.3	38.8	DYFRE10J	34.9	32.1	29.5	27.8	25.3	30						
200 YR ON SAC 115K ON AMER	DFRE20J	37.9	428000	38.7	90000	29.7	113000	29.9	107000	24.6	107000	39.2	35.3	39.2	DYFRE20J	35.7	32.8	30	28.3	25.6	30.5						
400 YR ON SAC 115K ON AMER	DREF40J	38	440000	38.8	91000	29.8	114000	29.9	107000	24.6	107000	39.2	35.3	39.4	DYFRE40J	36	33	30.2	28.5	25.7	30.7						

------LEVEE FAILURE LOCATIONS------
A. RIGHT BANK AMERICAN RIVER ABOVE H-STREET
B. LEFT BANK AMERICAN RIVER MAYHEW DRAIN AREA
C. RIGHT BANK FLOW RETURN TO AMERICAN RIVER
D. RIGHT BANK AMERICAN RIVER BELOW NEMDC
E. RIGHT BANK SAC RIVER (AREA C)
F. WEST LEVEE NATOMAS EAST MAIN DRAIN

----- COMPUTATIONAL POINT LOCATIONS -----
FREMONT WEIR - FREMONT WEIR WEST END (LOCATION 37 ON CHART 1).
VERONA - SACRAMENTO RIVER AT VERONA (LOCATION 34 ON CHART 1).
SAC WEIR - SACRAMENTO RIVER AT NORTH END OF THE SAC WEIR.
I-STREET - SACRAMENTO RIVER AT I-STREET (LOCATION 46 ON CHART 1).
FREEPORT - SACRAMENTO RIVER AT FREEPORT (LOCATION 47 ON CHART 1).
H-STREET - AMERICAN RIVER AT H-STREET (LOCATION 45 ON CHART 1).
MAIN AVE - NEMDC JUST DOWNSTREAM OF DRY CREEK
HIWAY 99 - CROSS CANAL AT HIGHWAY 99 CROSSING
RIDGE CUT - YOLO BYPASS AT KNIGHTS LANDING RIDGE CUT (NEAR LOCATION 39 ON CHART 1)
WOODLAND - YOLO BYPASS AT WOODLAND (LOCATION 40 ON CHART 1).
D/S SAC BYPASS - YOLO BYPASS JUST DOWNSTREAM OF THE SACRAMENTO BYPASS
SHIP CHANNEL - YOLO BYPASS APPROXIMATELY 1 MILE DOWNSTREAM OF INTERSTATE 80.
LISBON - YOLO BYPASS AT LISBON (LOCATION 49 ON CHART 1).
SAC BYPASS - MIDPOINT BETWEEN SAC WEIR AND YOLO BYPASS

FILE SAC17
JH 5/16/90

A1-T60
U1-AZ60

APPENDIX A

REFERENCES

A. Mr. James Goodridge, Retired State of California Climatologist

B. NOAA ATLAS 2, Volume XI, California

C. Standard Project Criteria for General Rain Storms, April 1971, preliminary

D. Dry Creek, Placer and Sacramento Counties, Hydrology Office Report, July 1984, revised April 1988

E. Sacramento County and Sacramento City, California, Flood Insurance Study, Hydrology Internal Office Report, January 1975.

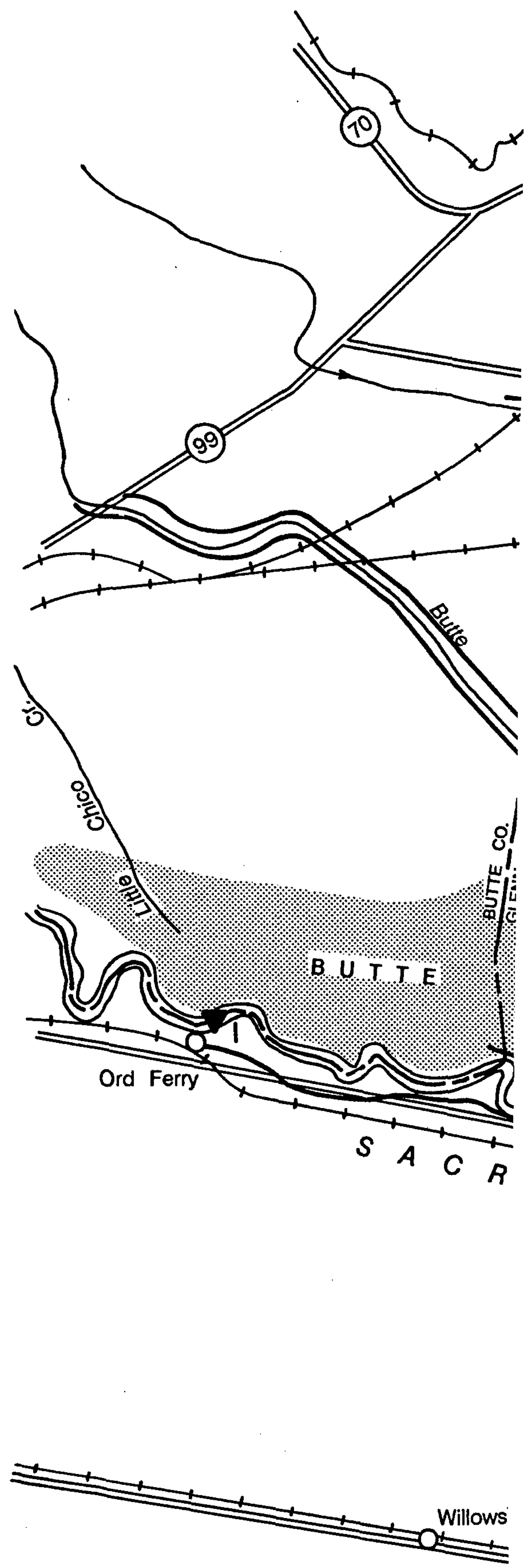
F. Special Study on the Lower American River, California March 1987

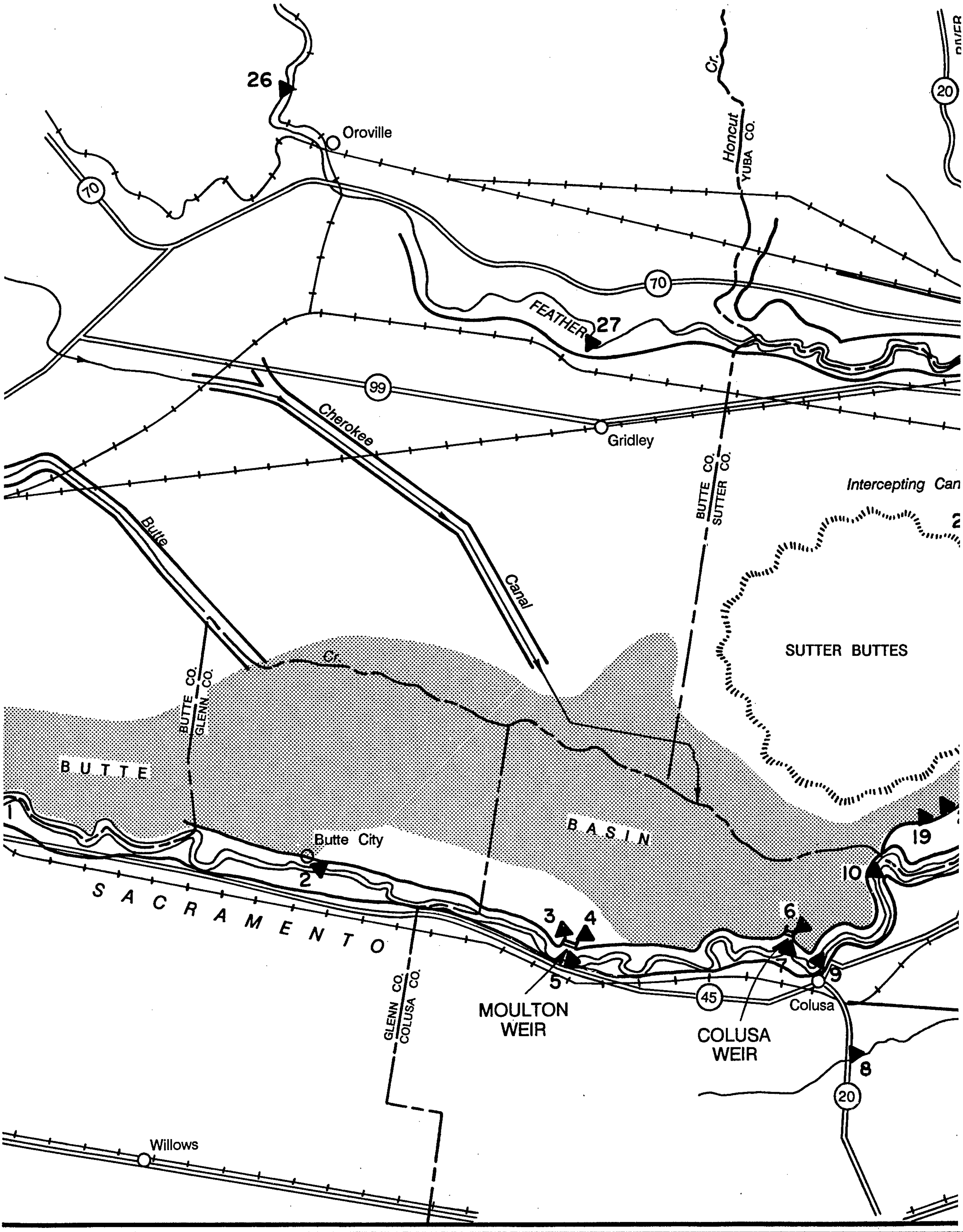
G. Morrison Creek Streamgroup, California, Hydrology Design Memorandum, July 1985

H. Hydrometeorological Report No. 36, Interim Report Probable Maximum Precipitation In California

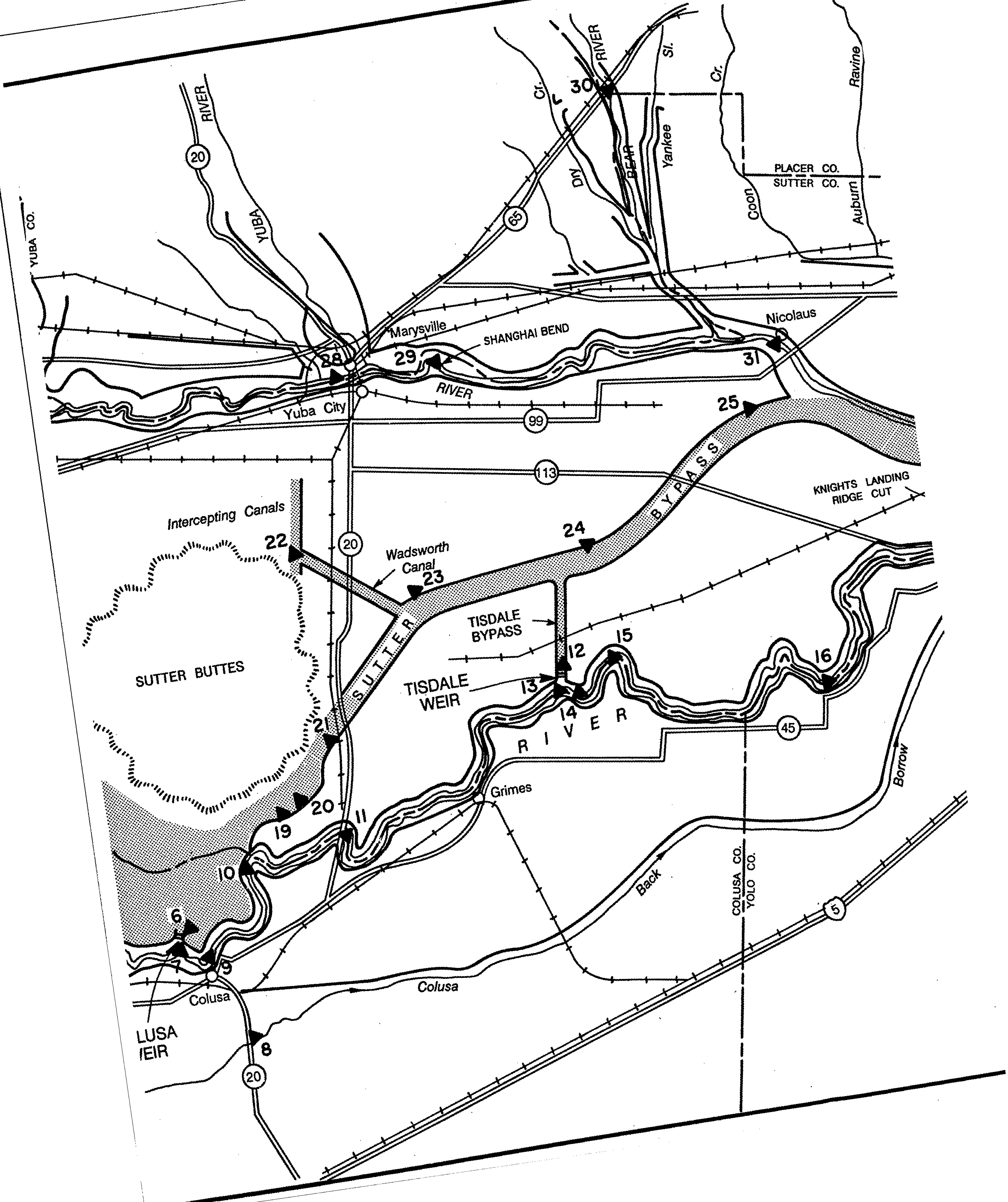
STREAM GAGING STATIONS

1. Sacramento River @ Ord Ferry
2. Sacramento River @ Butte City
3. Moulton Weir Spill to Butte Basin
4. Sacramento River @ Moulton Weir
5. Sacramento River Opposite Moulton Weir
6. Colusa Weir Spill to Butte Basin
7. Sacramento River @ Colusa Weir
8. Colusa Basin Drain @ Highway 20
9. Sacramento River @ Colusa
10. Sacramento River @ Butte Slough - Outfall Gates
11. Sacramento River @ Meridian
12. Tisdale Weir Spill to Sutter Bypass
13. Sacramento River @ Tisdale Weir
14. Sacramento River Below Tisdale Weir
15. Sacramento River Below Wilkins Slough
16. Reclamation District 108 Drainage to Sacramento River
17. Colusa Basin Drain @ Knights Landing
18. Sacramento River @ Knights Landing
19. Butte Slough @ Outfall Gates
20. Butte Slough @ Mawson Bridge
21. Sutter Bypass @ Long Bridge
22. Wadsworth Canal @ Butte House Road
23. Sutter Bypass @ State Pumping Plant #3
24. Sutter Bypass @ State Pumping Plant #2
25. Sutter Bypass @ State Pumping Plant #1
26. Feather River Near Oroville
27. Feather River Near Gridley
28. Feather River @ Yuba City
29. Feather River Below Shanghai Bend
30. Bear River Near Wheatland
31. Feather River @ Nicolaus
32. Sutter Bypass @ Reclamation District 1500 Pumping Plant
33. Sacramento Slough @ Sacramento River
34. Sacramento River @ Verona
35. Yolo Bypass @ Elkhorn
36. Sacramento River Opposite Sacramento Weir
37. Sacramento River @ Fremont Weir West End
38. Sacramento River @ Fremont Weir East End
39. Fremont Weir Spill to Yolo Bypass
40. Yolo Bypass Near Woodland
41. Yolo Bypass Above Sacramento Bypass
42. Sacramento Weir Spill to Yolo Bypass
43. Sacramento River @ Sacramento Weir
44. American River @ "H" Street
45. Sacramento River @ "I" Street
46. Sacramento River Near Freeport
47. Sacramento River @ Clarksburg
48. Sacramento River @ Snodgrass Slough
49. Yolo Bypass Near Lisbon

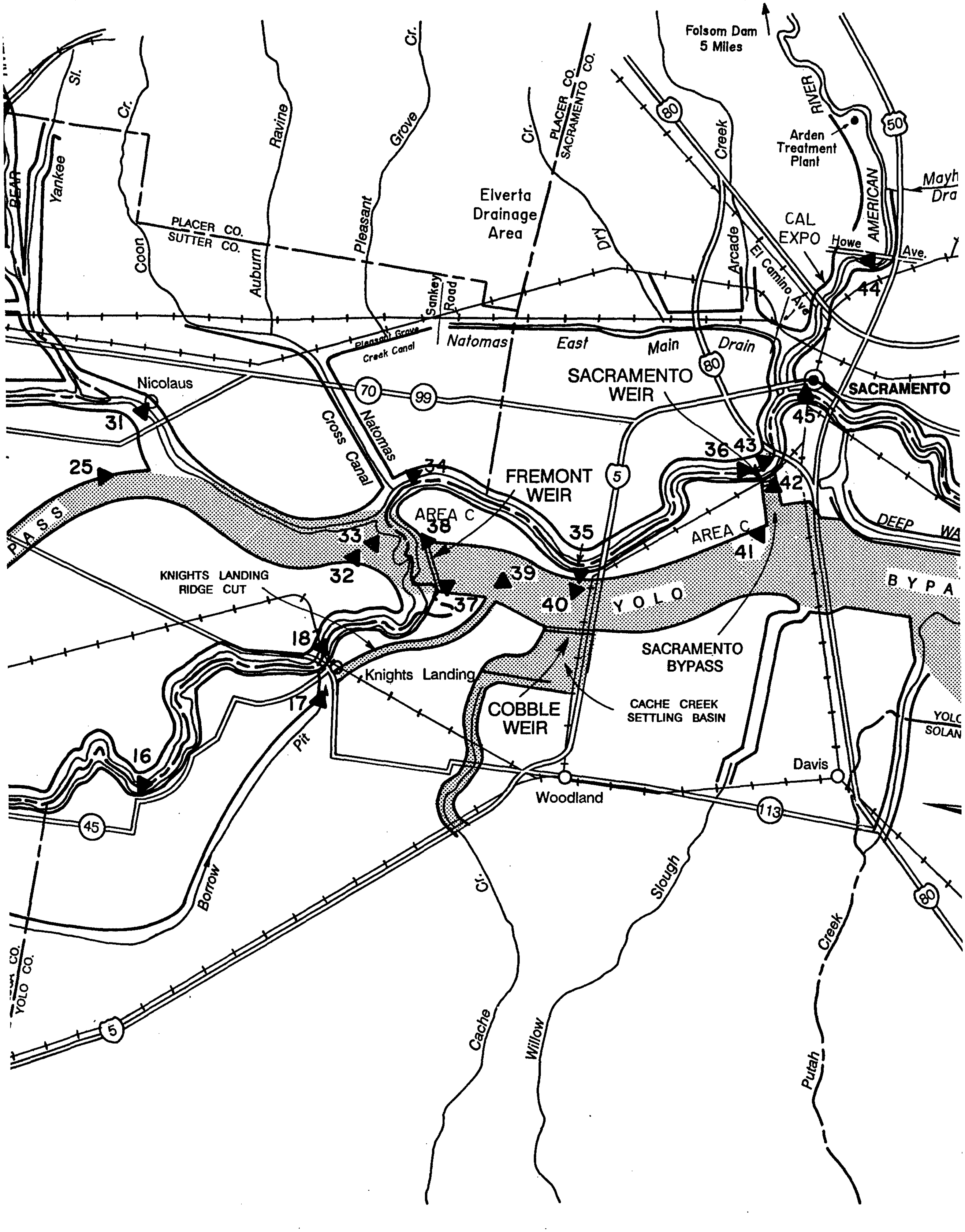




26
Oroville
70
Cr.
Honcut
YUBA CO.
20
70
FEATHER
27
99
Cherokee
Gridley
BUTTE CO.
SUTTER CO.
Intercepting Can
Butte
Canal
Cr.
SUTTER BUTTES
BUTTE CO.
GLENN CO.
BUTTE
BASIN
19
Butte City
2
10
SACRAMENTO
3
4
6
5
9
MOULTON WEIR
45
Colusa
GLENN CO.
COLUSA CO.
COLUSA WEIR
8
20
Willows



YUBA CO.
RIVER
YUBA
20
65
Cr.
Dry
30
RIVER
BEAR
Sl.
Yankee
Cr.
Coon
Ravine
Auburn
PLACER CO.
SUTTER CO.
Marysville
SHANGHAI BEND
28
29
RIVER
Yuba City
99
Nicolaus
31
25
113
BYPASS
KNIGHTS LANDING RIDGE CUT
Intercepting Canals
22
Wadsworth Canal
23
24
TISDALE BYPASS
SUTTER BUTTES
SUTTER
TISDALE WEIR
12
13
14
15
16
RIVER
45
21
Grimes
Borrow
19
20
11
10
Back
COLUSA CO.
YOLO CO.
6
9
Colusa
5
LUSA
/EIR
8



Folsom Dam
5 Miles
Arden
Treatment
Plant
AMERICAN
RIVER
CAL
EXPO
Howe Ave.
El Camino Ave
Arcade Creek
Dry Cr.
PLACER CO.
SACRAMENTO CO.
Elverta
Drainage
Area
PLACER CO.
SUTTER CO.
Coon Cr.
Auburn Ravine
Pleasant Grove Cr.
Sankey Road
Pleasant Grove Creek Canal
Natomas East Main Drain
Yankee Sl.
BEAR
Nicolaus
Natomas Cross Canal
SACRAMENTO
WEIR
SACRAMENTO
FREMONT
WEIR
AREA C
YOLO BYPASS
DEEP WA
KNIGHTS LANDING
RIDGE CUT
Knights Landing
COBBLE
WEIR
CACHE CREEK
SETTLING BASIN
SACRAMENTO
BYPASS
Woodland
Davis
YOLO
SOLAN
Borrow Pit
Cache Cr.
Willow Slough
Putah Creek
YOLO CO.
16
17
18
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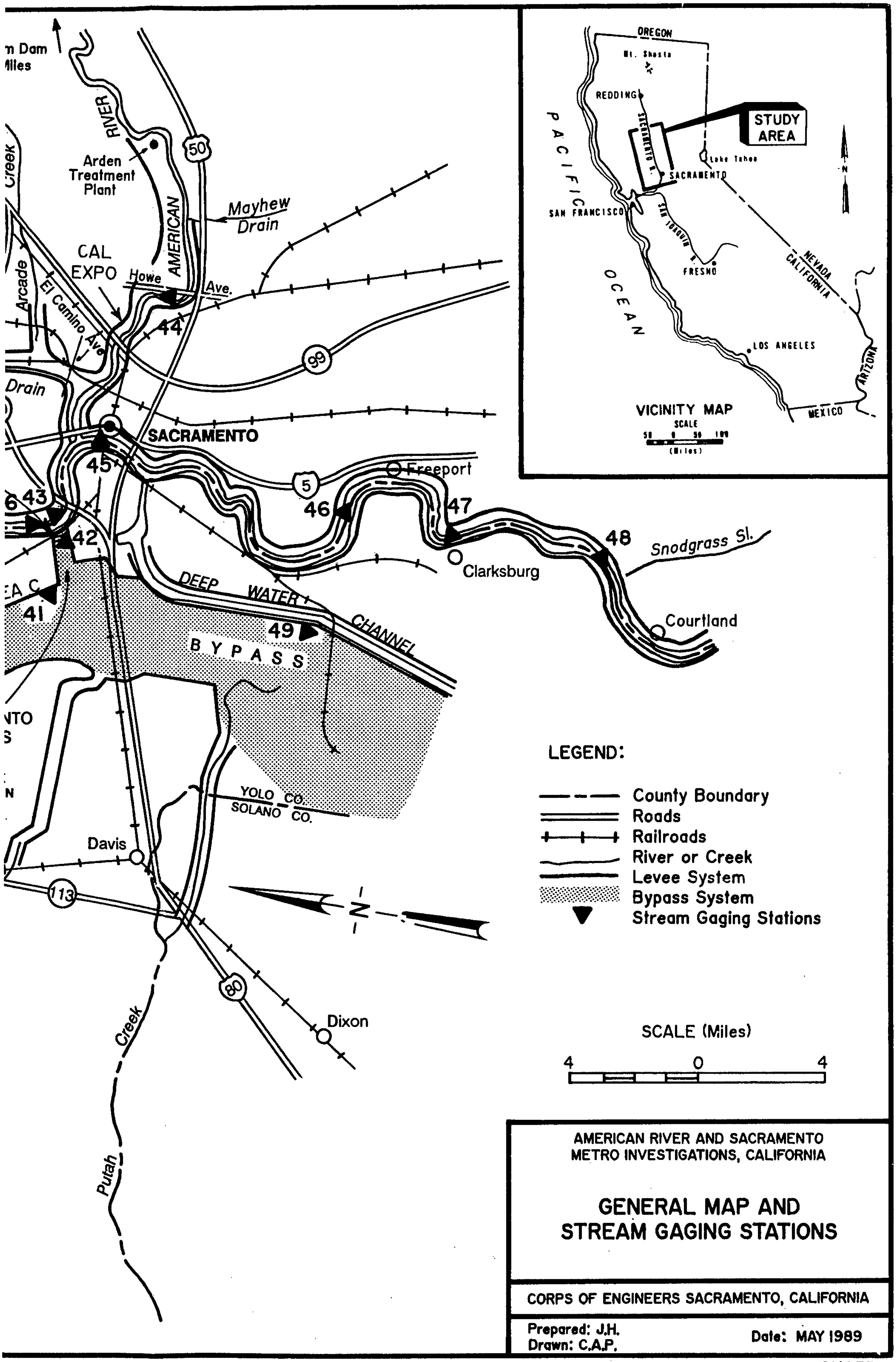


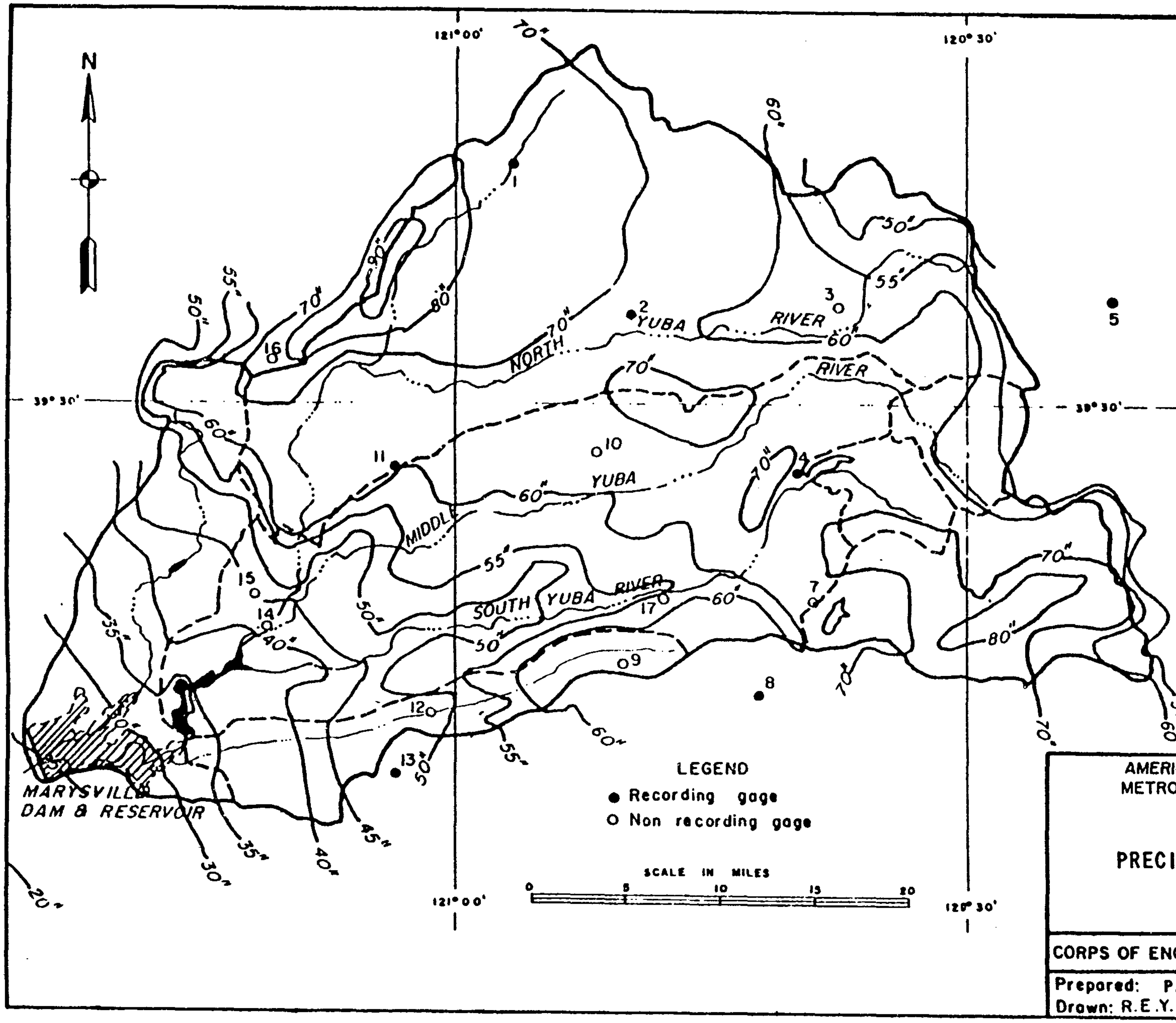
AMERICAN RIVER AND SACRAMENTO METRO INVESTIGATIONS, CALIFORNIA

GENERAL MAP AND STREAM GAGING STATIONS

CORPS OF ENGINEERS SACRAMENTO, CALIFORNIA

Prepared: J.H.
Drawn: C.A.P.

Date: MAY 1989



No	STATION NAME
1	LA PORTE
2	DOWNIEVILLE
3	SIERRA CITY
4	BOWMAN DAM
5	SIERRAVILLE R.S.
6	TRUCKEE R.S.
7	FULLER LAKE
8	BLUE CANYON
9	DEER CREEK P.H.
10	ALLEGHANY
11	CAMPTONVILLE
12	NEVADA CITY
13	GRASS VALLEY
14	COLGATE POWER HOUSE
15	DOBBINS
16	WOODLEAF
17	WASHINGTON

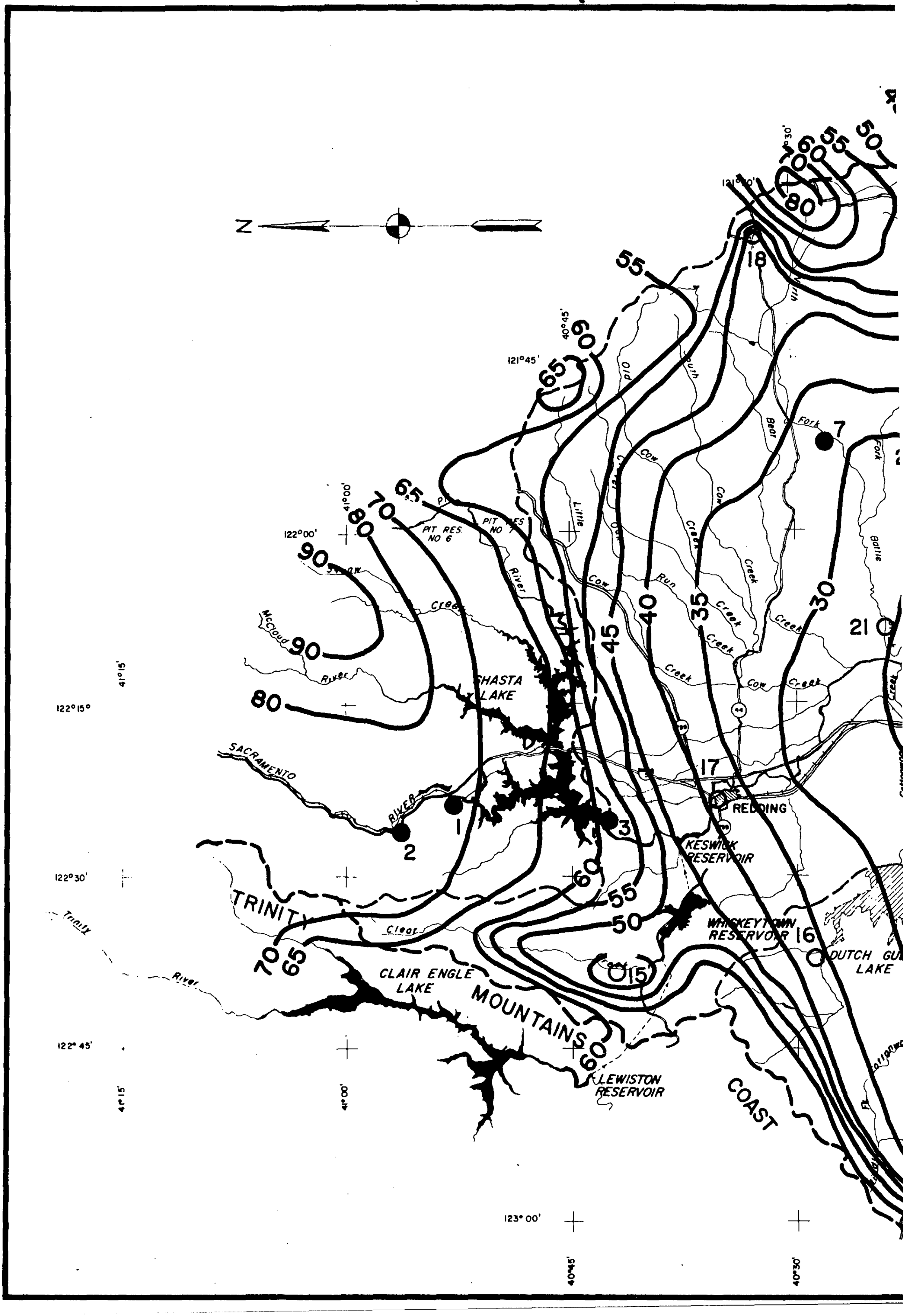
AMERICAN RIVER AND SACRAMENTO
METRO INVESTIGATIONS, CALIFORNIA

NORMAL ANNUAL
PRECIPITATION & HYDROLOGIC
STATIONS MAP

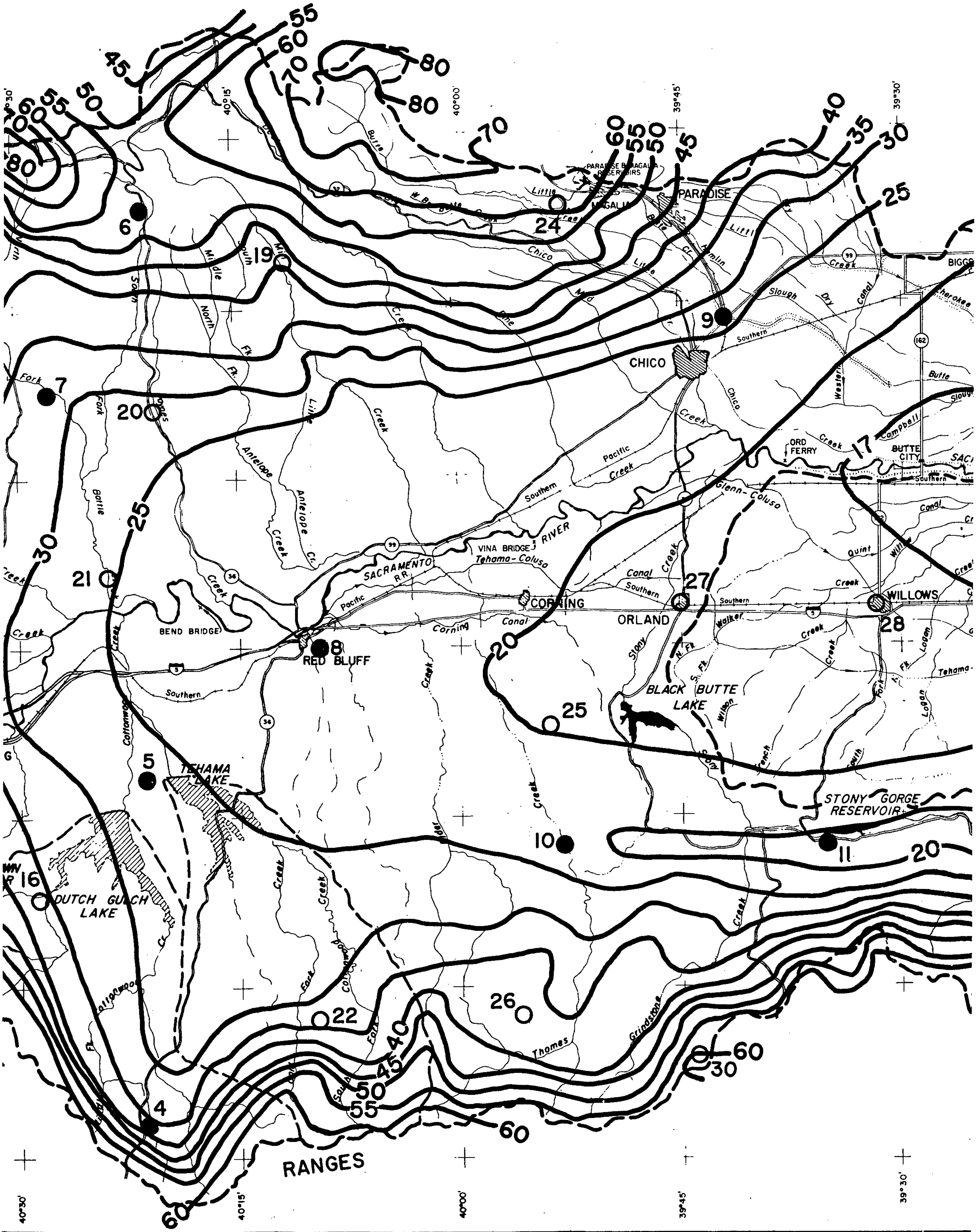
YUBA RIVER BASIN

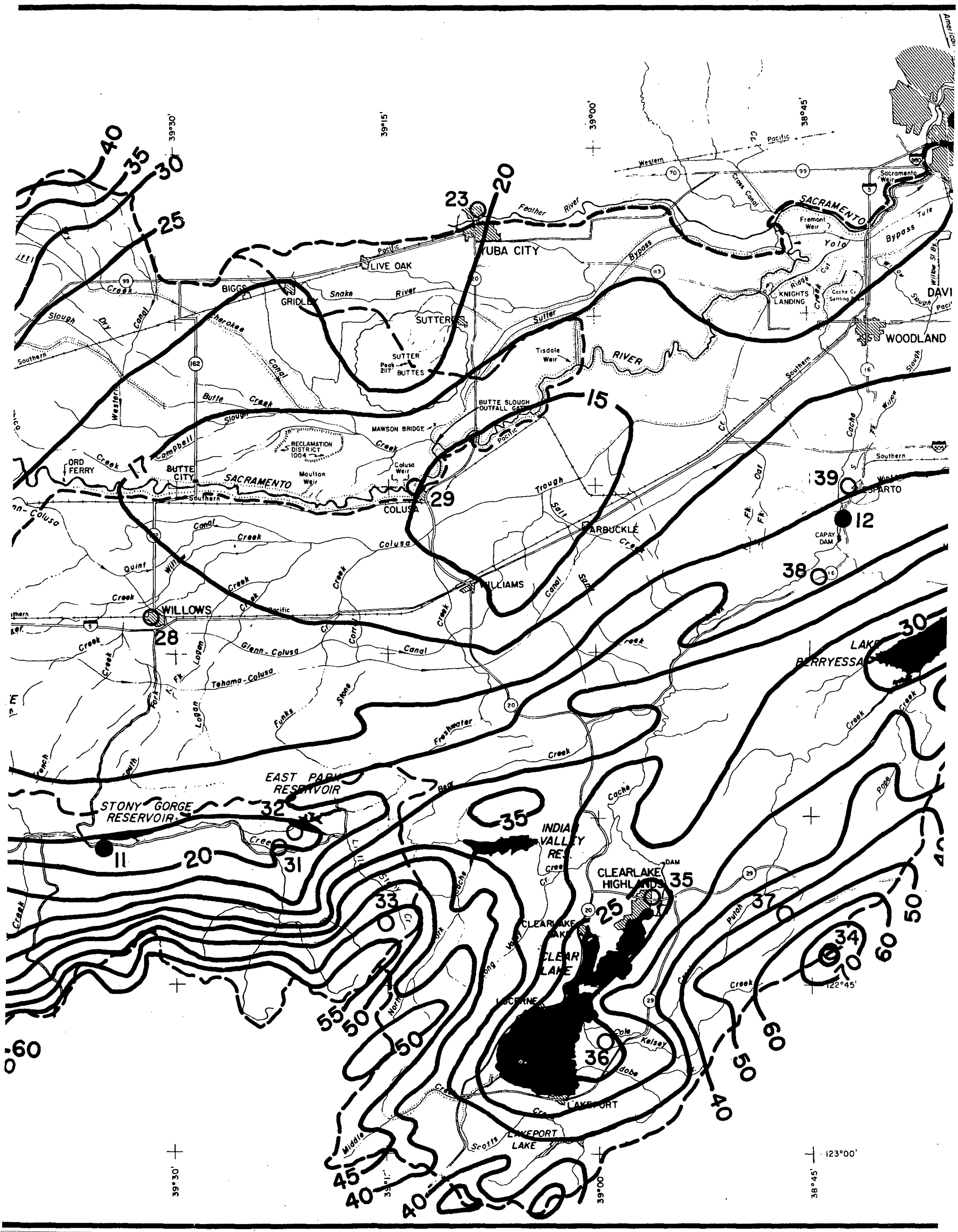
CORPS OF ENGINEERS, SACRAMENTO, CALIFORNIA

Prepared: P.W. - E.G.C.
Drawn: R.E.Y. & B.J.C.
Date: JANUARY 1990



SHASTA LAKE
REDDING
KESWICK RESERVOIR
WHISKEYTOWN RESERVOIR
DUTCH GU
LAKE
CLAIR ENGLE LAKE
LEWISTON RESERVOIR
TRINITY
MOUNTAINS
COAST
SACRAMENTO
RIVER
PIT RES. NO 6
PIT RES. NO 7
N
122°00'
122°15°
122°30'
122° 45'
123° 00'
121°45'
41°00'
41°15'
40°45'
40°30'


PARADISE
MAGALIA
CHICO
BIGGS
ORD FERRY
BUTTE CITY
SACRAMENTO RIVER
VINA BRIDGE
BEND BRIDGE
CORNING
ORLAND
WILLOWS
RED BLUFF
TEHAMA LAKE
BLACK BUTTE LAKE
STONY GORGE RESERVOIR
DUTCH GULCH LAKE
RANGES
40°30'
40°15'
40°00'
39°45'
39°30'



YUBA CITY
LIVE OAK
BIGGS
GRIDLEY
SUTTER
SUTTER BUTTES
Peak 2117
WOODLAND
KNIGHTS LANDING
Fremont Weir
Sacramento Weir
Tisdale Weir
BUTTE SLOUGH OUTFALL GATES
MAWSON BRIDGE
RECLAMATION DISTRICT 1004
ORD FERRY
BUTTE CITY
SACRAMENTO
Moulton Weir
Colusa Weir
COLUSA
ARBUCKLE
WILLIAMS
WILLOWS
ESPARTO
CAPAY DAM
LAKE BERRYESSA
EAST PARK RESERVOIR
STONY GORGE RESERVOIR
INDIAN VALLEY RES.
CLEARLAKE HIGHLANDS
CLEARLAKE OAKS
CLEAR LAKE
LUCERNE
LAKEPORT
LAKEPORT LAKE
Feather River
Snake River
Sutter Bypass
Yolo Bypass
Tule
Cache Creek
Glenn-Colusa Canal
Tehama-Colusa
Freshwater Creek
Putah Creek
39°30'
39°15'
39°00'
38°45'
123°00'
122°45'
40
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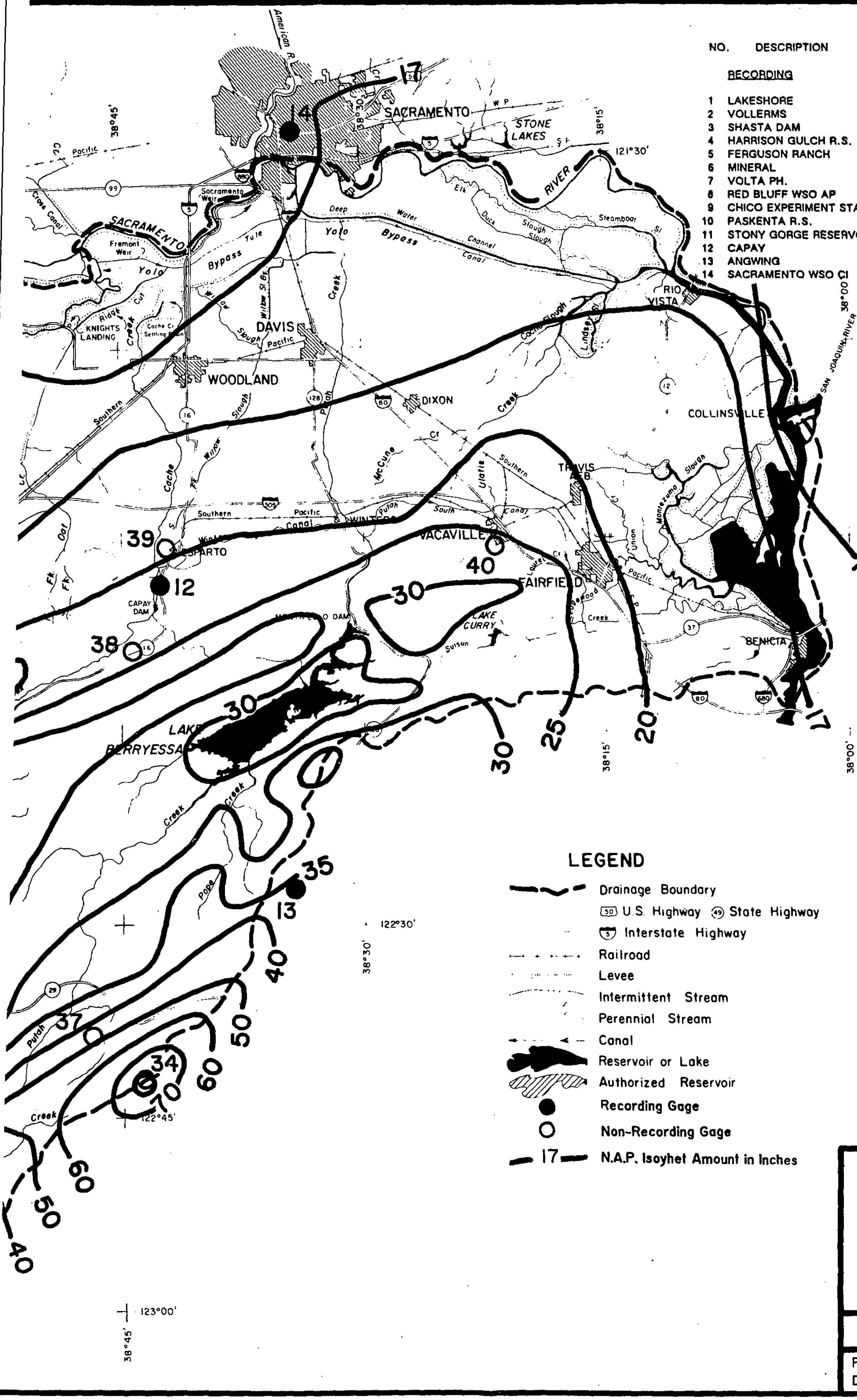
4



PRECIPITATION STATIONS

NO.	DESCRIPTION	NAP (Inches)	NO.	DESCRIPTION
	RECORDING			NON-RECORDING
1	LAKESHORE	71.9	15	FRENCH GULCH
2	VOLLERMS	70.1	16	ONO
3	SHASTA DAM	59.4	17	REDDING FIRE STA. #:
4	HARRISON GULCH R.S.	35.9	18	MANZANITA LAKE
5	FERGUSON RANCH	27.0	19	MCCARTHY POINT
6	MINERAL	52.4	20	PAYNES CREEK
7	VOLTA PH.	32.8	21	COLEMAN FISHERIES
8	RED BLUFF WSO AP	22.1	22	SADDLE CAMP R.S.
9	CHICO EXPERIMENT STA.	25.7	23	MARYSVILLE
10	PASKENTA R.S.	22.8	24	DE SABLE
11	STONY GORGE RESERVOIR	17.6	25	CORNING HOUGHTON
12	CAPAY	22.1	26	BALL MOUNTAIN LOO
13	ANGWING	37.4	27	ORLAND
14	SACRAMENTO WSO CI	18.1	28	WILLOWS
			29	COLUSA I SSW
			30	PLASKETT
			31	STONYFORD R.S.
			32	EAST PARK RESERVC
			33	STONYFORD COOLE\
			34	HELEN MINE
			35	KELSEYVILLE
			36	CLEAR LAKE HIGHLA
			37	HARBIN SPRING
			38	BROOKS
			39	ESPARTO
			40	VACAVILLE

AMERICAN RIVER AND
METRO INVESTIGATION

NORMAL A
PRECIPITAT

SACRAMENTO F

CORPS OF ENGINEERS, SAC

Prepared: T.G.K.
Drawn: T.K.B., T.G.K.
Da

SHE

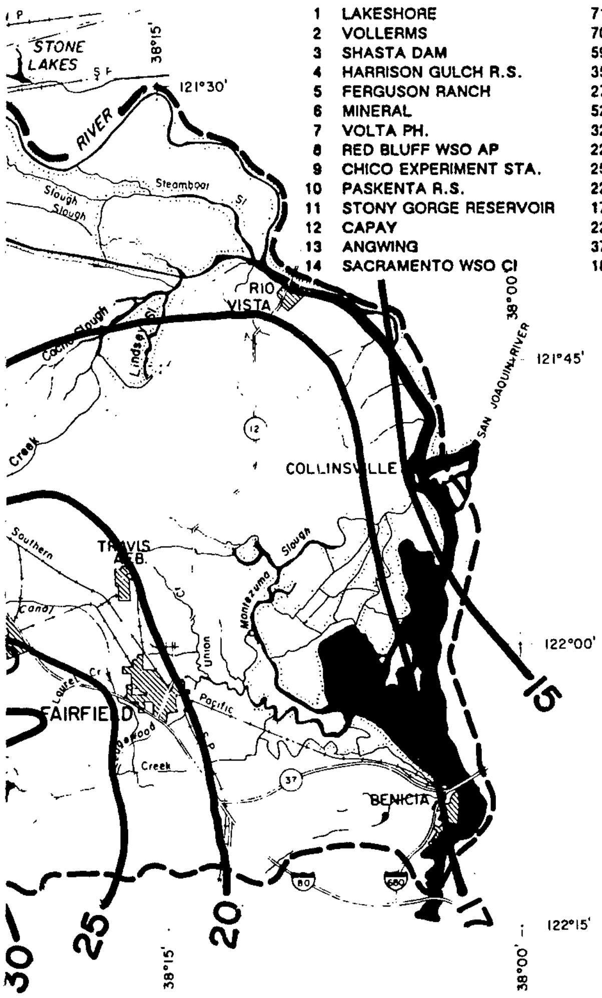
PRECIPITATION STATIONS

RECORDING

NO.	DESCRIPTION	NAP (Inches)
1	LAKESHORE	71.9
2	VOLLERMS	70.1
3	SHASTA DAM	59.4
4	HARRISON GULCH R.S.	35.9
5	FERGUSON RANCH	27.0
6	MINERAL	52.4
7	VOLTA PH.	32.8
8	RED BLUFF WSO AP	22.1
9	CHICO EXPERIMENT STA.	25.7
10	PASKENTA R.S.	22.8
11	STONY GORGE RESERVOIR	17.6
12	CAPAY	22.1
13	ANGWING	37.4
14	SACRAMENTO WSO CI	18.1

NON-RECORDING

NO.	DESCRIPTION	NAP (Inches)
15	FRENCH GULCH	39.9
16	ONO	36.9
17	REDDING FIRE STA. #2	40.6
18	MANZANITA LAKE	44.2
19	MCCARTHY POINT	40.8
20	PAYNES CREEK	29.4
21	COLEMAN FISHERIES STA.	25.2
22	SADDLE CAMP R.S.	30.6
23	MARYSVILLE	20.6
24	DE SABLE	63.4
25	CORNING HOUGHTON RANCH	19.8
26	BALL MOUNTAIN LOOKOUT	39.5
27	ORLAND	18.2
28	WILLOWS	17.1
29	COLUSA I SSW	13.7
30	PLASKETT	58.9
31	STONYFORD R.S.	20.1
32	EAST PARK RESERVOIR	18.4
33	STONYFORD COOLEY RANCH	54.6
34	HELEN MINE	80.0
35	KELSEYVILLE	23.0
36	CLEAR LAKE HIGHLANDS	23.6
37	HARBIN SPRING	42.7
38	BROOKS	20.5
39	ESPARTO	17.5
40	VACAVILLE	26.1



LEGEND

- Drainage Boundary
- 50 U.S Highway 49 State Highway
- 5 Interstate Highway
- Railroad
- Levee
- Intermittent Stream
- Perennial Stream
- Canal
- Reservoir or Lake
- Authorized Reservoir
- Recording Gage
- Non-Recording Gage
- 17 N.A.P. Isoyhet Amount in Inches

SCALE

5 0 5 10 15 20

(Statute Miles)

AMERICAN RIVER AND SACRAMENTO METRO INVESTIGATIONS, CALIFORNIA

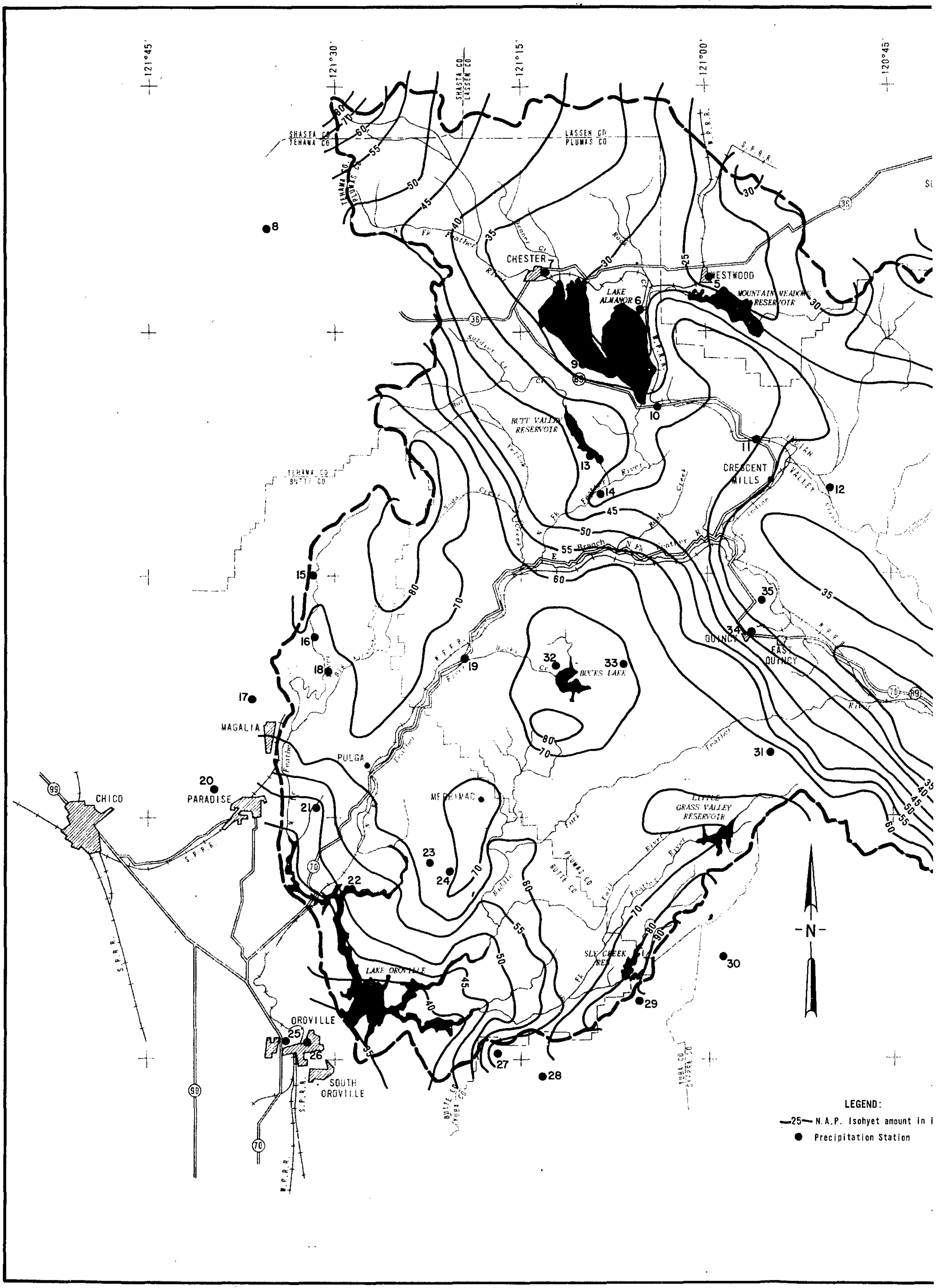
NORMAL ANNUAL PRECIPITATION MAP

SACRAMENTO RIVER BASIN

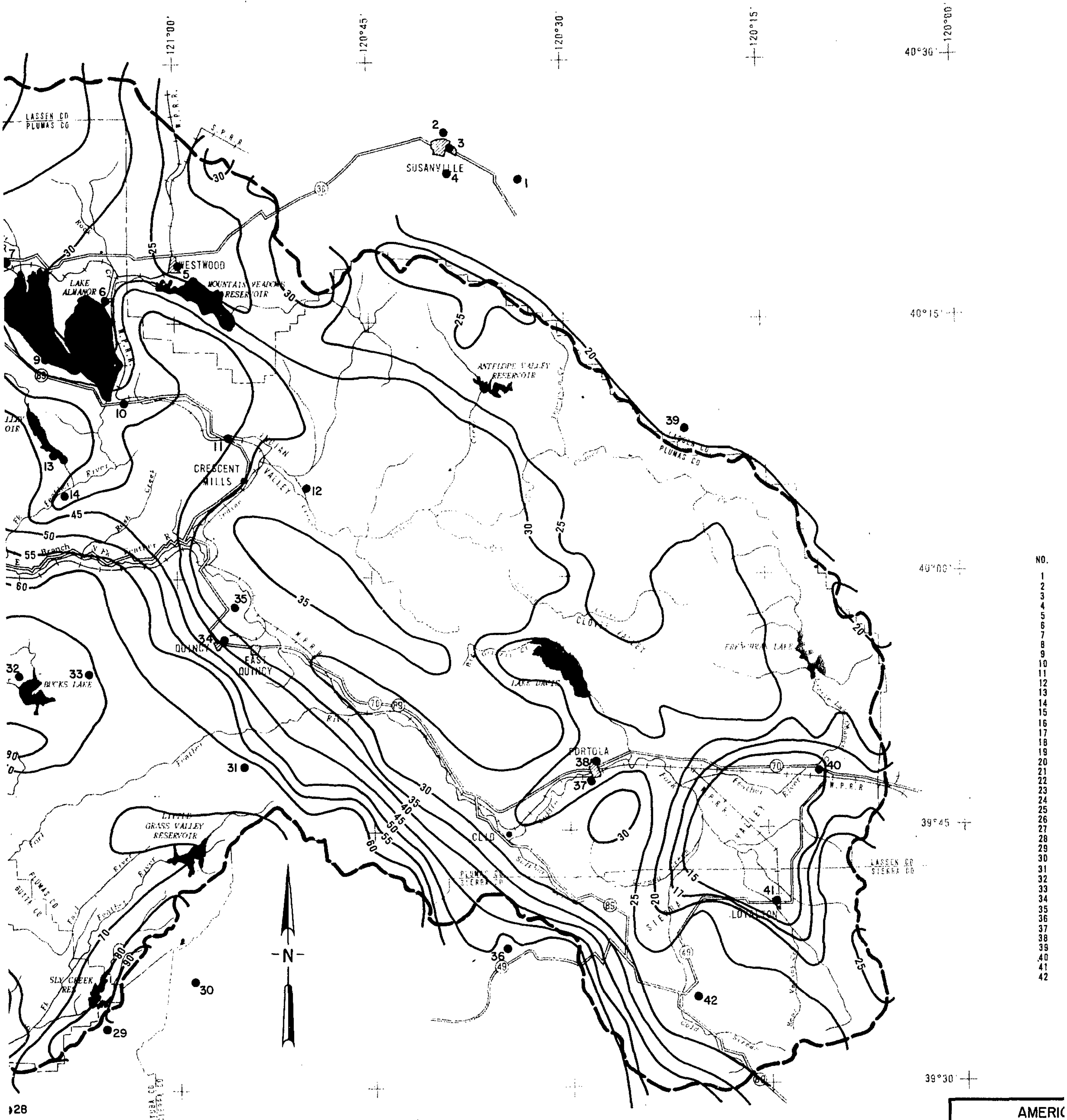
CORPS OF ENGINEERS, SACRAMENTO, CALIFORNIA

Prepared: T.G.K.
Drawn: T.K.B., T.G.K.

Date: JANUARY 1990


121°45'
121°30'
121°15'
121°00'
120°45'
SHASTA CO
LASSEN CO
TEHAMA CO
PLUMAS CO
BUTTE CO
YUBA CO
CHESTER
WESTWOOD
LAKE ALMANOR
MOUNTAIN MEADOWS RESERVOIR
BUTT VALLEY RESERVOIR
CRESCENT MILLS
QUINCY
EAST QUINCY
BUCKS LAKE
MAGALIA
PULGA
CHICO
PARADISE
MERRIMAC
LITTLE GRASS VALLEY RESERVOIR
SLY CREEK RES
LAKE OROVILLE
OROVILLE
SOUTH OROVILLE
S.P.R.R.
W.P.R.R.
-N-
LEGEND:
25 N.A.P. Isohyet amount in i
Precipitation Station

2



LEGEND:

—25— N.A.P. Isohyet amount in inches

● Precipitation Station

SCALE

5 0 5

(Miles)

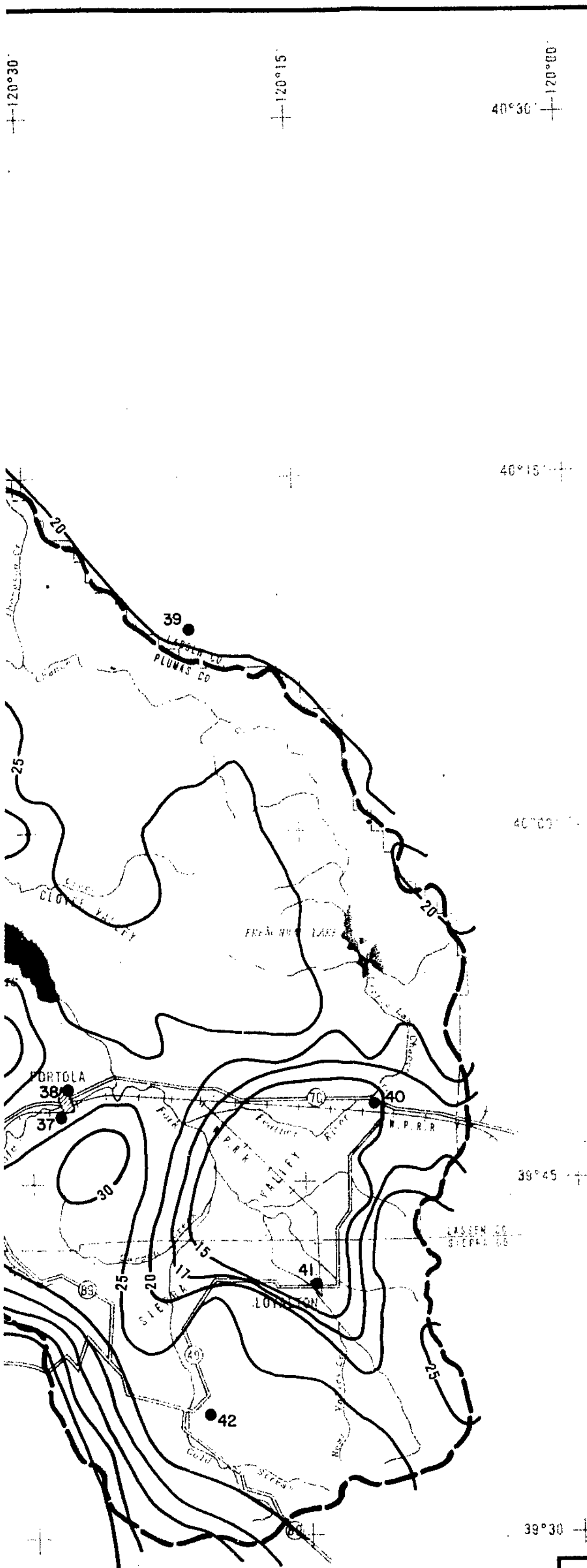
AMERIC
METRO

NC
PRE

FE.

CORPS OF ENG

Prepared: R.C.K.
Drawn: C.A.P.



PRECIPITATION STATIONS

NO.	DESCRIPTION	N.A.P. (inches)
1	Susanville AP	12.9
2	Susanville 1 WNW	15.9
3	Susanville	15.1
4	Susanville ST RS	14.6
5	Westwood	22.9
6	Hamilton Branch PH	27.0
7	Chester	33.2
8	Mineral	51.4
9	Prattville No. 2	34.9
10	Canyon Dam	37.5
11	Greenville RS	40.5
12	Veramont	31.8
13	Butt Valley	42.9
14	Caribou PH	38.1
15	Inskip Inn	74.3
16	West Branch	67.4
17	DeSabla	63.4
18	Stirling City RS	68.7
19	Bucks Creek PH	64.2
20	Centerville PH	42.1
21	Lake Wilenor	48.8
22	Las Plumas	51.9
23	Stanwood	62.3
24	Brush Creek RS	69.9
25	Oroville Bridge	27.4
26	Oroville 1 N	27.4
27	Forbestown	65.8
28	Challenger RS	65.9
29	Strawberry Valley	85.2
30	Scales	76.2
31	Onion Valley	60.8
32	Bucks Lake	76.7
33	Edmonton	70.1
34	Quincy RS	39.4
35	Feather River Exp. Stn.	33.4
36	Camp Pioneer	52.9
37	Portola	21.0
38	Portola 2	22.4
39	Milford Laufman RS	17.3
40	Vinton	14.0
41	Loyalton	14.5
42	Sierraville RS	27.8

SCALE
5 0 5
(Miles)

AMERICAN RIVER AND SACRAMENTO
METRO INVESTIGATIONS, CALIFORNIA

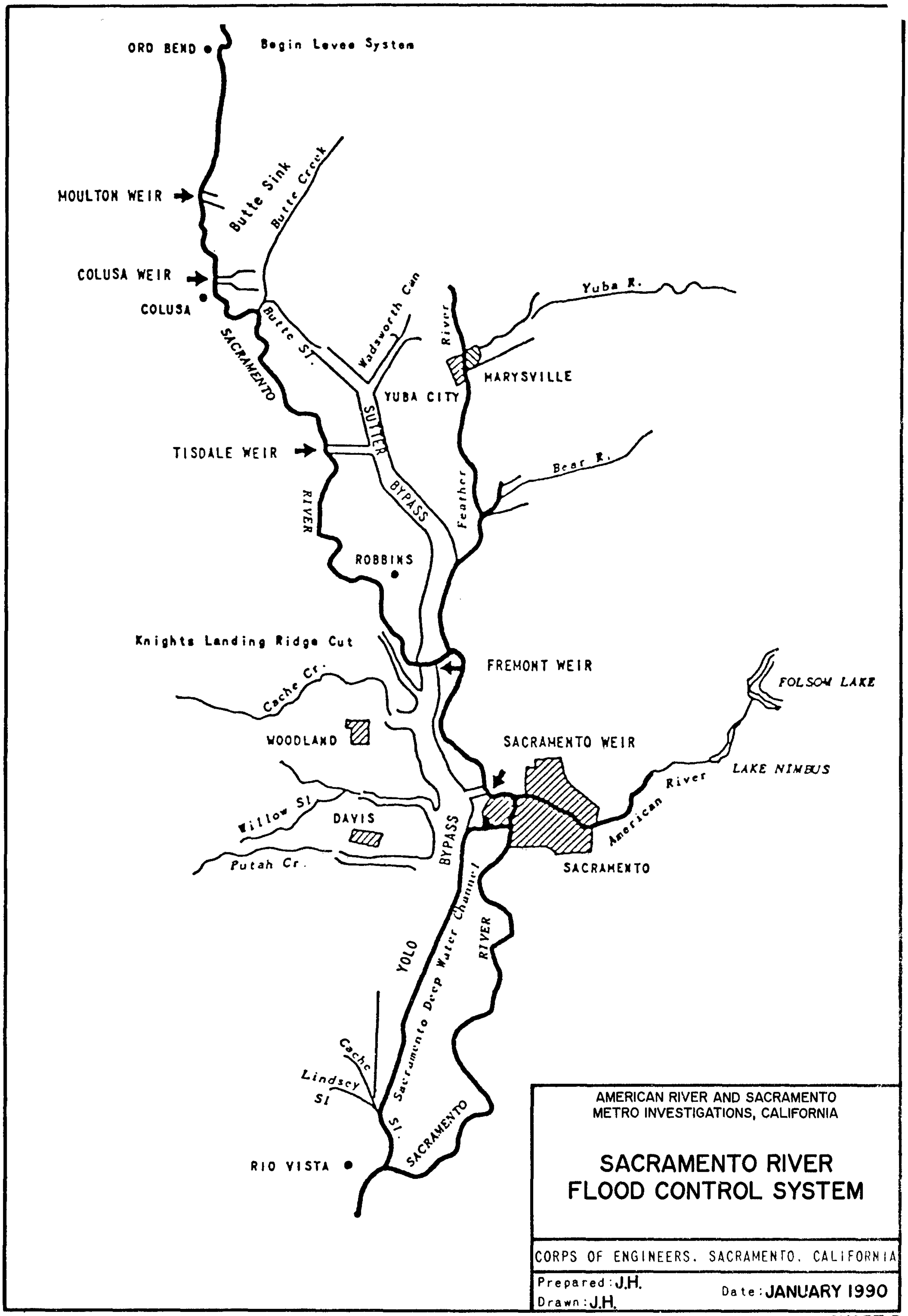
NORMAL ANNUAL PRECIPITATION MAP

FEATHER RIVER BASIN

CORPS OF ENGINEERS SACRAMENTO, CALIFORNIA

Prepared: R.C.K.
Drawn: C.A.P.

Date: JANUARY 1990



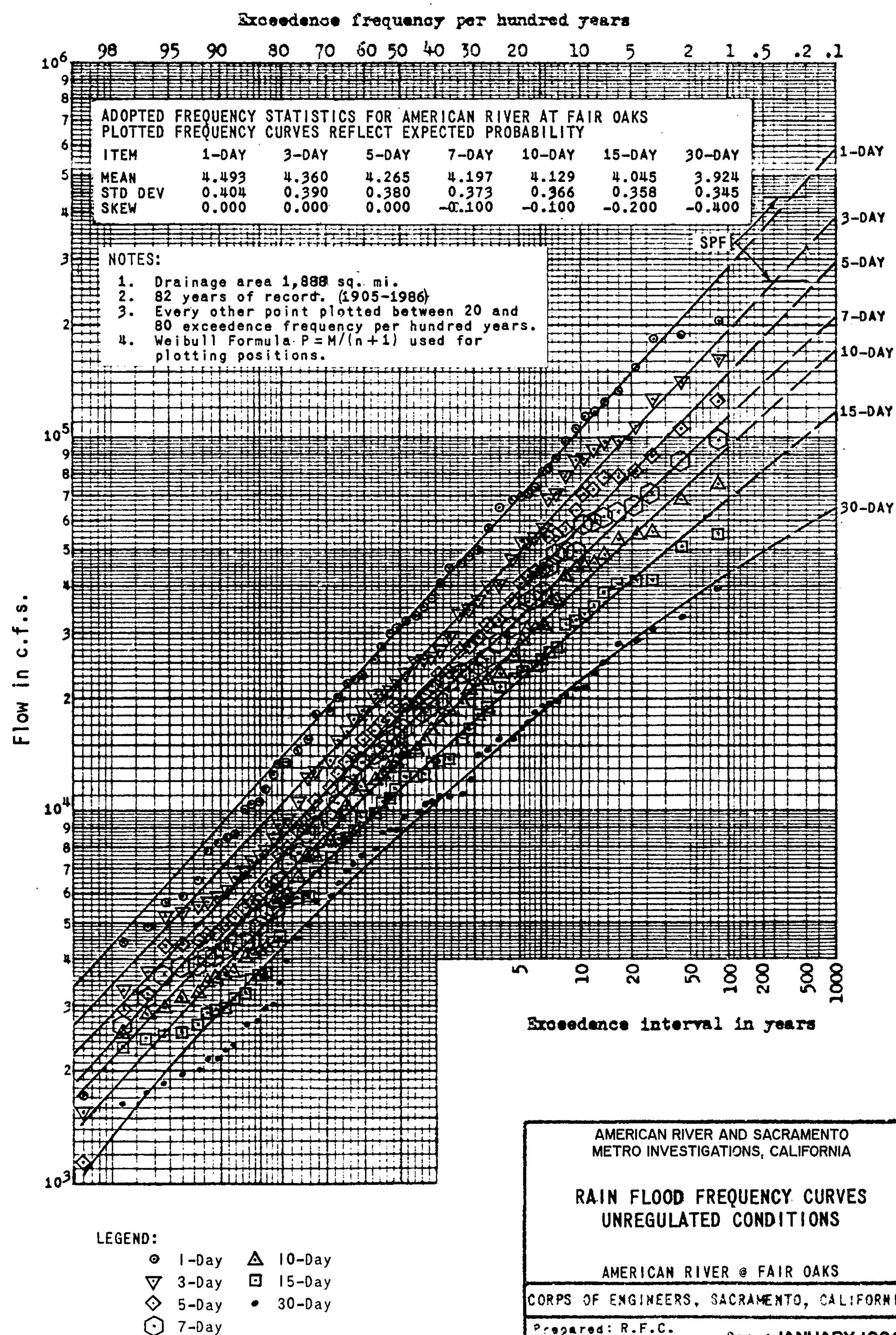
AMERICAN RIVER AND SACRAMENTO METRO INVESTIGATIONS, CALIFORNIA

SACRAMENTO RIVER FLOOD CONTROL SYSTEM

CORPS OF ENGINEERS. SACRAMENTO. CALIFORNIA

Prepared: J.H.
Drawn: J.H.
Date: JANUARY 1990

CHART 3



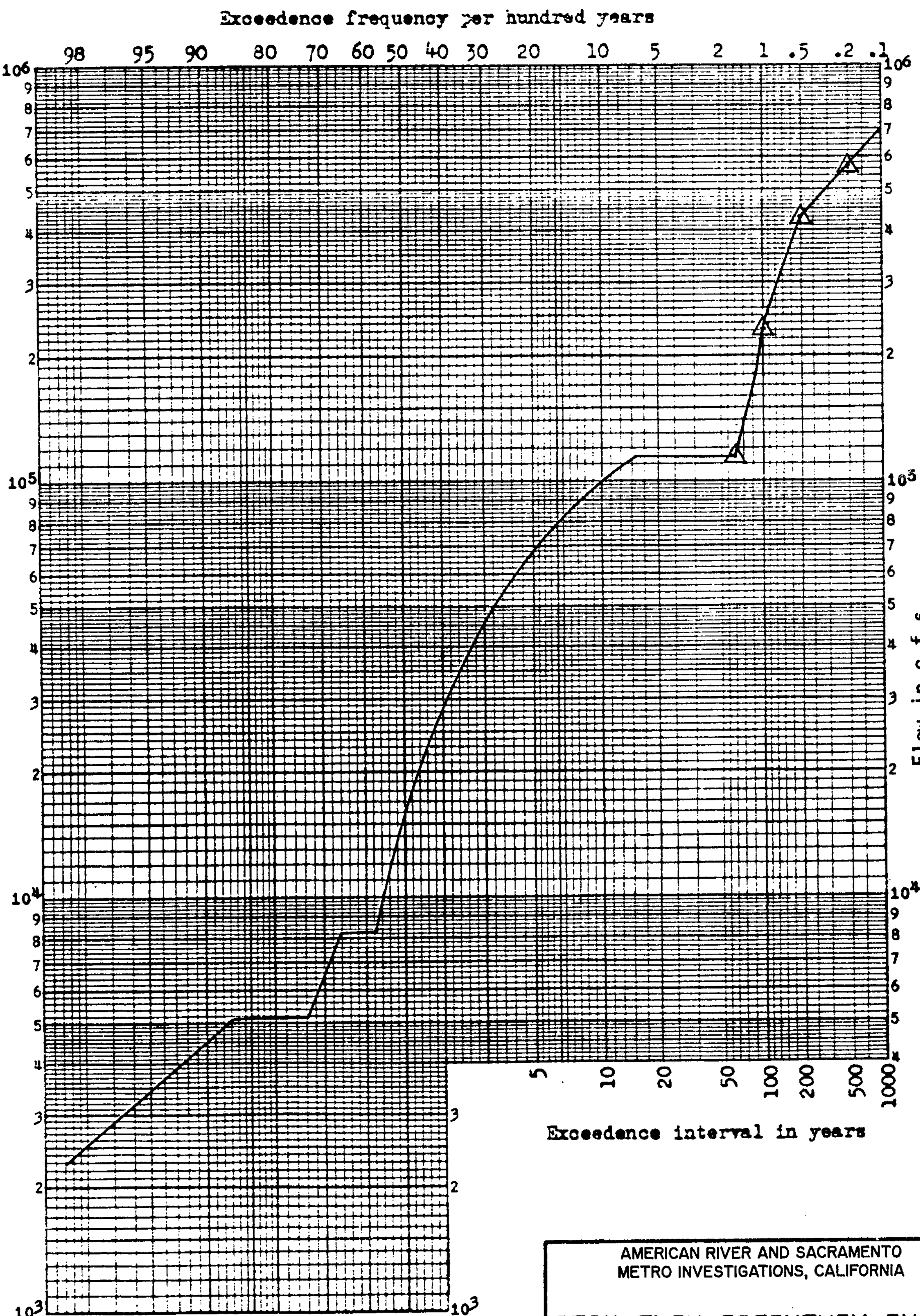
AMERICAN RIVER AND SACRAMENTO
METRO INVESTIGATIONS, CALIFORNIA

RAIN FLOOD FREQUENCY CURVES
UNREGULATED CONDITIONS

AMERICAN RIVER @ FAIR OAKS

CORPS OF ENGINEERS, SACRAMENTO, CALIFORNIA

Prepared: R.F.C.
Drawn: C.A.P.
Date: JANUARY 1990



Notes:

1. The project curves, to the 50 year event, reflects 32 years of record (1955-1986).
2. The remaining portion of the curve reflect the results of hypothetical flood routings as represented by the plotted points.
3. The hypothetical routings used the present authorized flood operation of Folsom Dam.

AMERICAN RIVER AND SACRAMENTO
METRO INVESTIGATIONS, CALIFORNIA

PEAK FLOW—FREQUENCY CURVE
EXISTING CONDITIONS

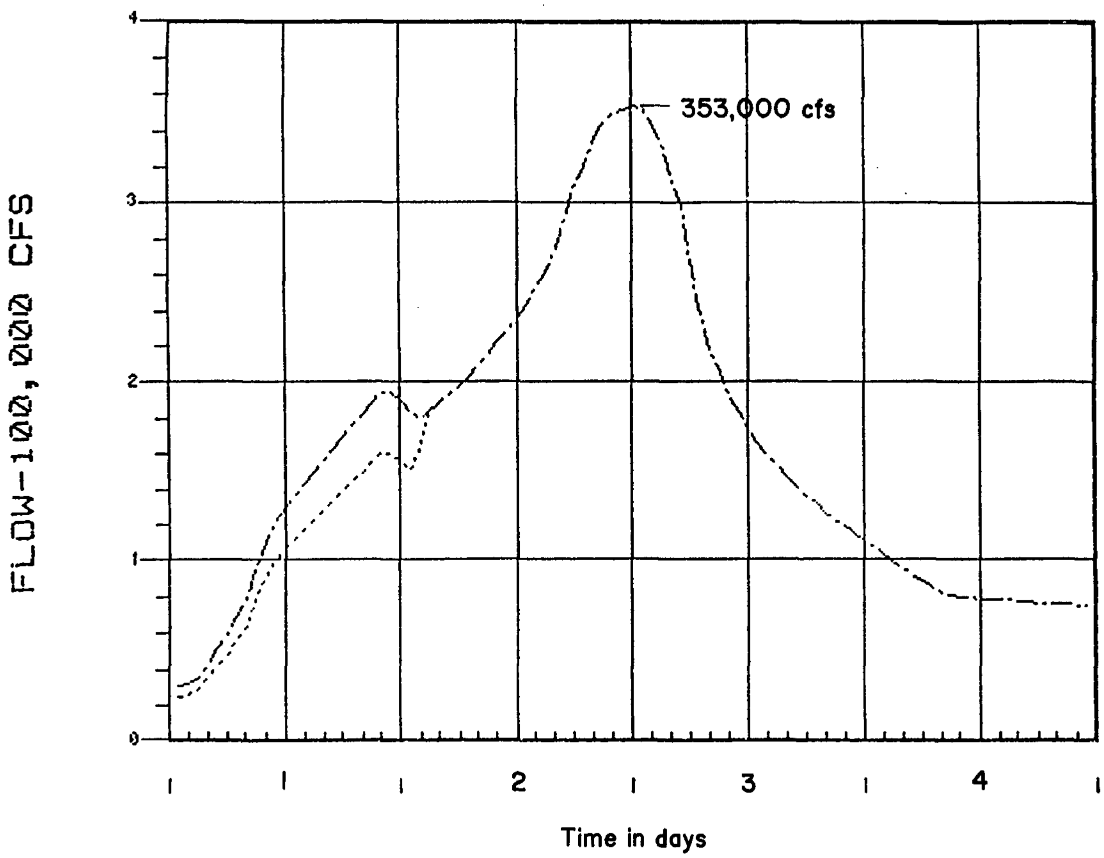
AMERICAN RIVER @ FAIR OAKS

CORPS OF ENGINEERS, SACRAMENTO, CALIFORNIA

Prepared: R.F.C.
Drawn: C.A.P.

Date: JANUARY 1990

CHART 5



LEGEND:

Unregulated flow

Regulated inflow
(Flow reduction due to storage in existing upstream reservoir).

AMERICAN RIVER AND SACRAMENTO
METRO INVESTIGATIONS, CALIFORNIA

100-YEAR FLOOD HYDROGRAPH

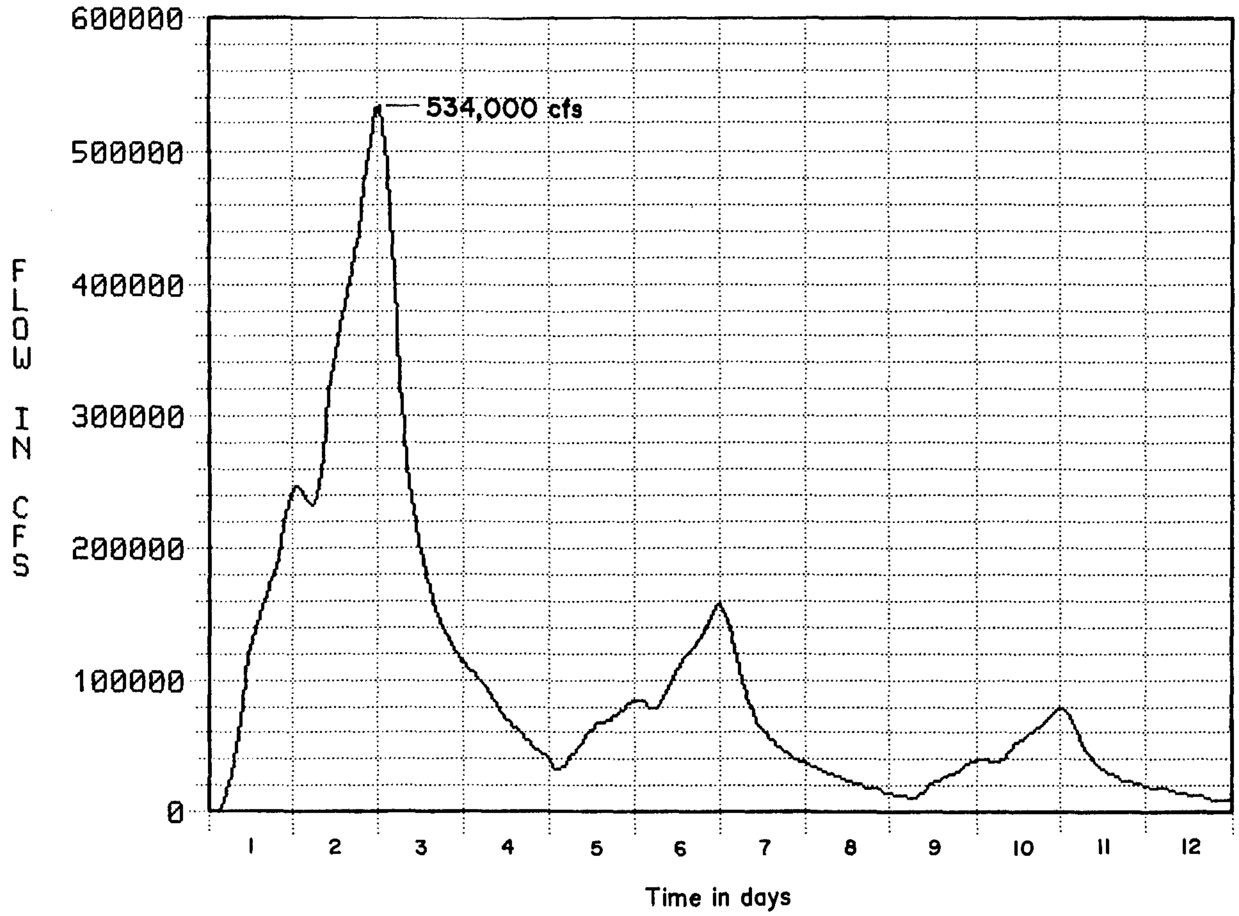
FOLSOM RESERVOIR INFLOW

CORPS OF ENGINEERS, SACRAMENTO, CALIFORNIA

Prepared: R.F.C.
Drawn: C.A.P.

Date: JANUARY 1990

CHART 6



AMERICAN RIVER AND SACRAMENTO
METRO INVESTIGATIONS, CALIFORNIA

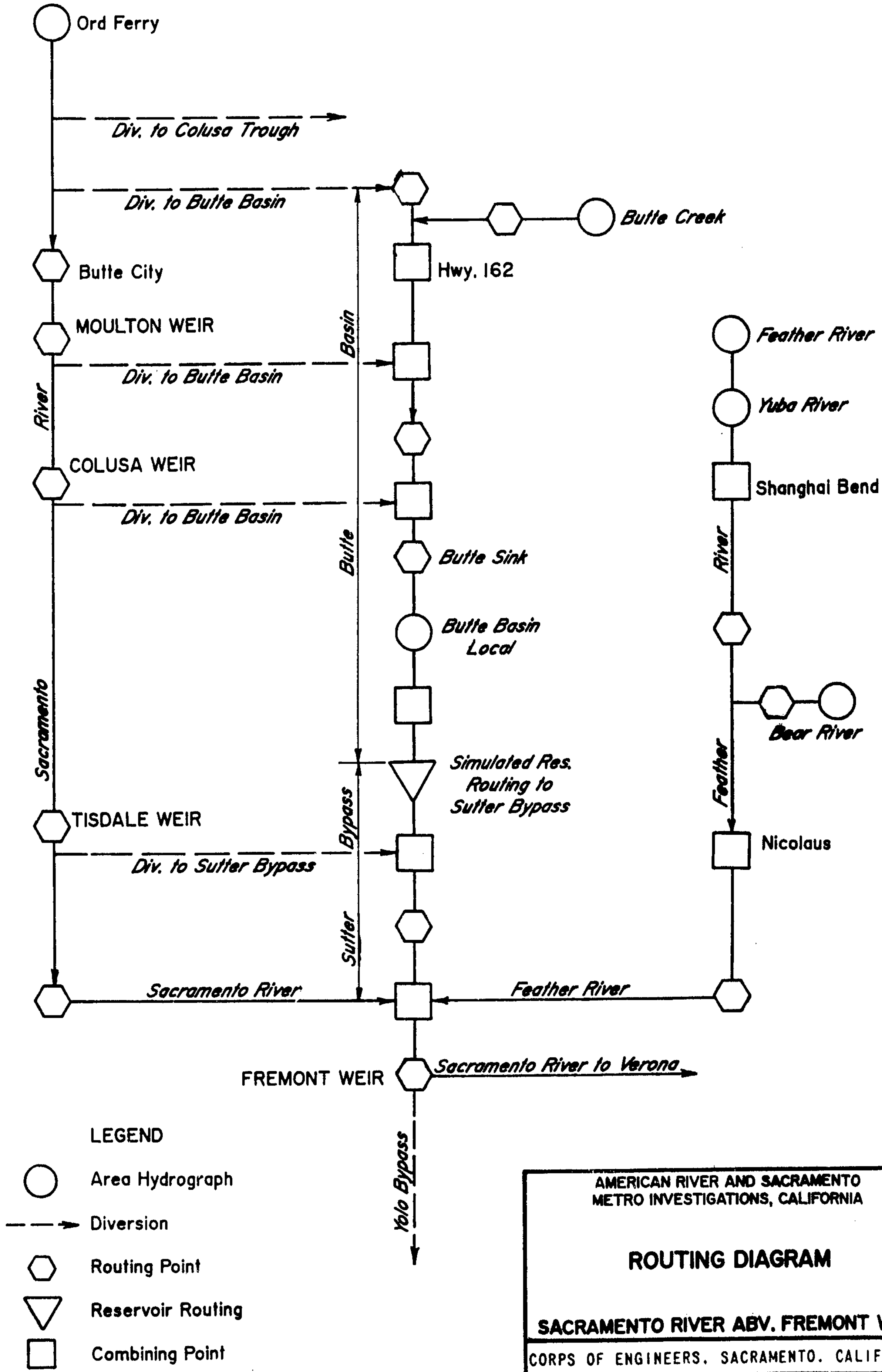
STANDARD PROJECT FLOOD HYDROGRAPH

INFLOW INTO FOLSOM RESERVOIR

CORPS OF ENGINEERS. SACRAMENTO. CALIFORNIA

Prepared: J.H.
Drawn: C.A.P.
Date: JANUARY 1990

CHART 7



AMERICAN RIVER AND SACRAMENTO METRO INVESTIGATIONS, CALIFORNIA

ROUTING DIAGRAM

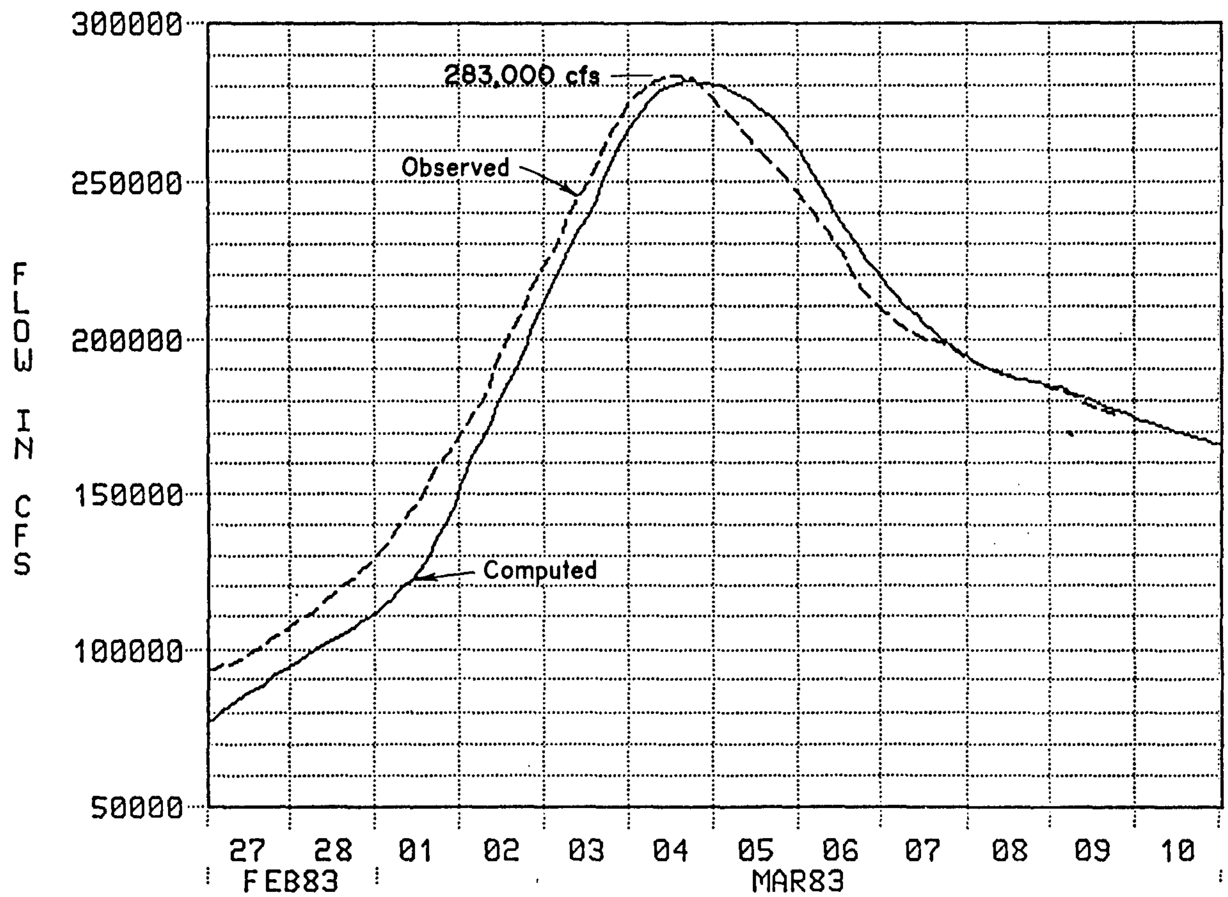
SACRAMENTO RIVER ABV. FREMONT WEIR

CORPS OF ENGINEERS, SACRAMENTO, CALIFORNIA

Prepared: R.F.C.
Drawn: C.A.P.

Date: JANUARY 1990

CHART 8



AMERICAN RIVER AND SACRAMENTO
METRO INVESTIGATIONS, CALIFORNIA

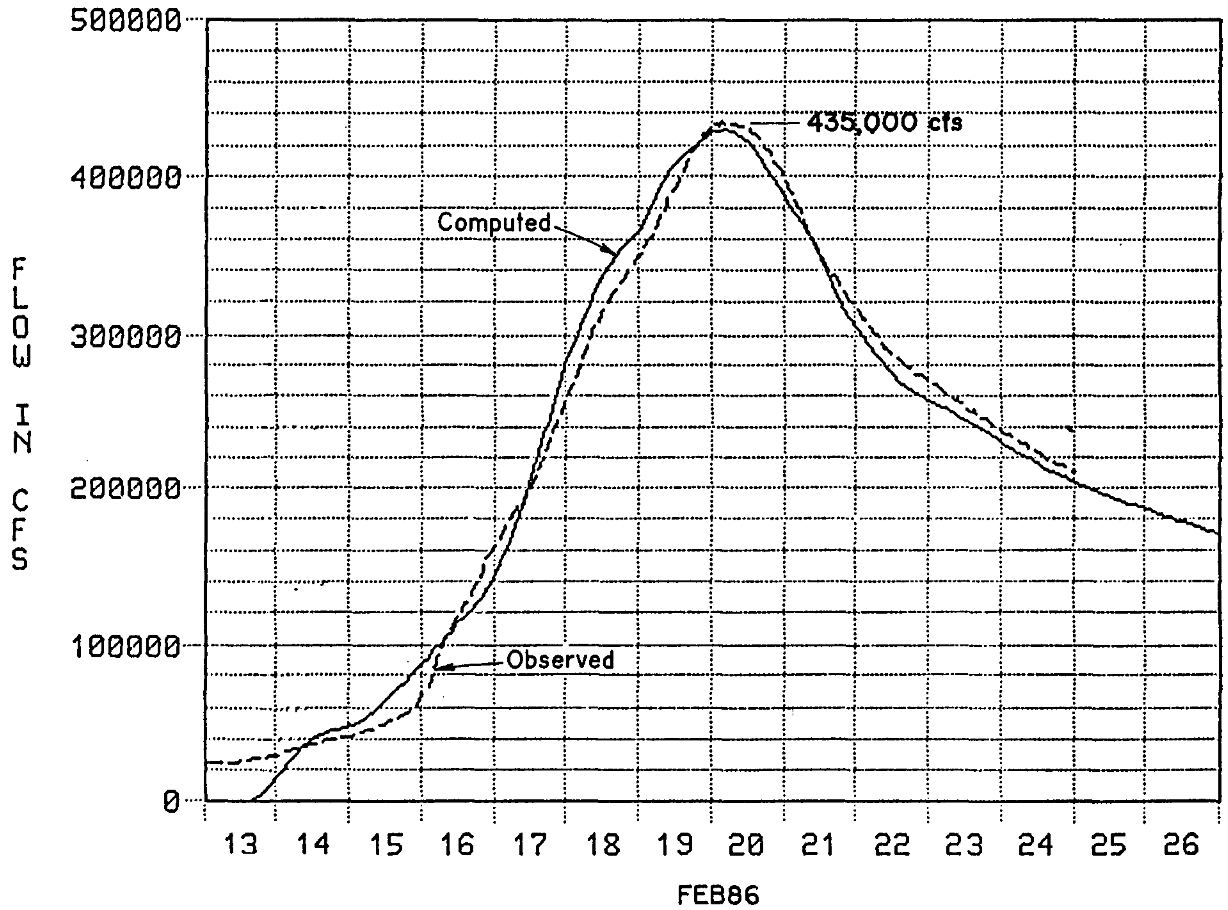
1983 COMPUTED & OBSERVED HYDROGRAPHS

SACRAMENTO AND FEATHER RIVER CONFLUENCE

CORPS OF ENGINEERS, SACRAMENTO, CALIFORNIA

Prepared: R.F.C.
Drawn: C.A.P.
Date: JANUARY 1990

CHART 9



AMERICAN RIVER AND SACRAMENTO
METRO INVESTIGATIONS, CALIFORNIA

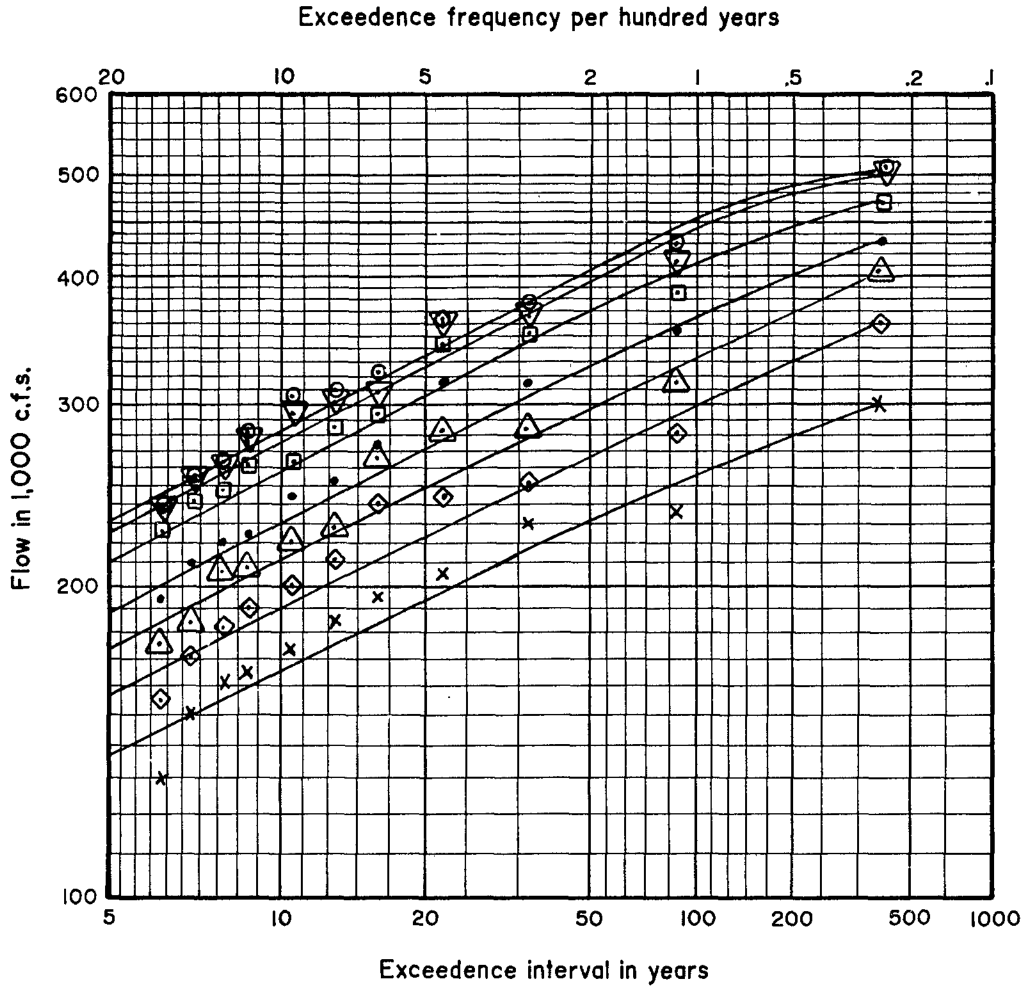
1986 COMPUTED & OBSERVED HYDROGRAPHS

SACRAMENTO AND FEATHER RIVER CONFLUENCE

CORPS OF ENGINEERS, SACRAMENTO, CALIFORNIA

Prepared: R.F.C.
Drawn: C.A.P.
Date: JANUARY 1990

CHART 10



PEAK AND VOLUME STATISTICS FOR
PRESENT CONDITION FREQUENCY CURVES

Log of	Peak	1-Day	3-Day	5-Day	7-Day	10-Day	15-Day
Mean	2.200	2.193	2.165	2.115	2.080	2.040	1.980
Std. Dev.	0.198	0.196	0.196	0.193	0.191	0.188	.0185
Skew	0	0	0	0	0	0	0

LEGEND

- ⊙ Peak
- ▽ 1-Day
- ⊡ 3-Day
- • 5-Day
- △ 7-Day
- ◇ 10-Day
- × 15-Day

1. Plotted points between the .6 and .01 event are regulated historical flows.
2. Plotted points beyond the .01 event are regulated hypothetical floods.

AMERICAN RIVER AND SACRAMENTO
METRO INVESTIGATIONS, CALIFORNIA

FLOOD FLOW FREQUENCY CURVES

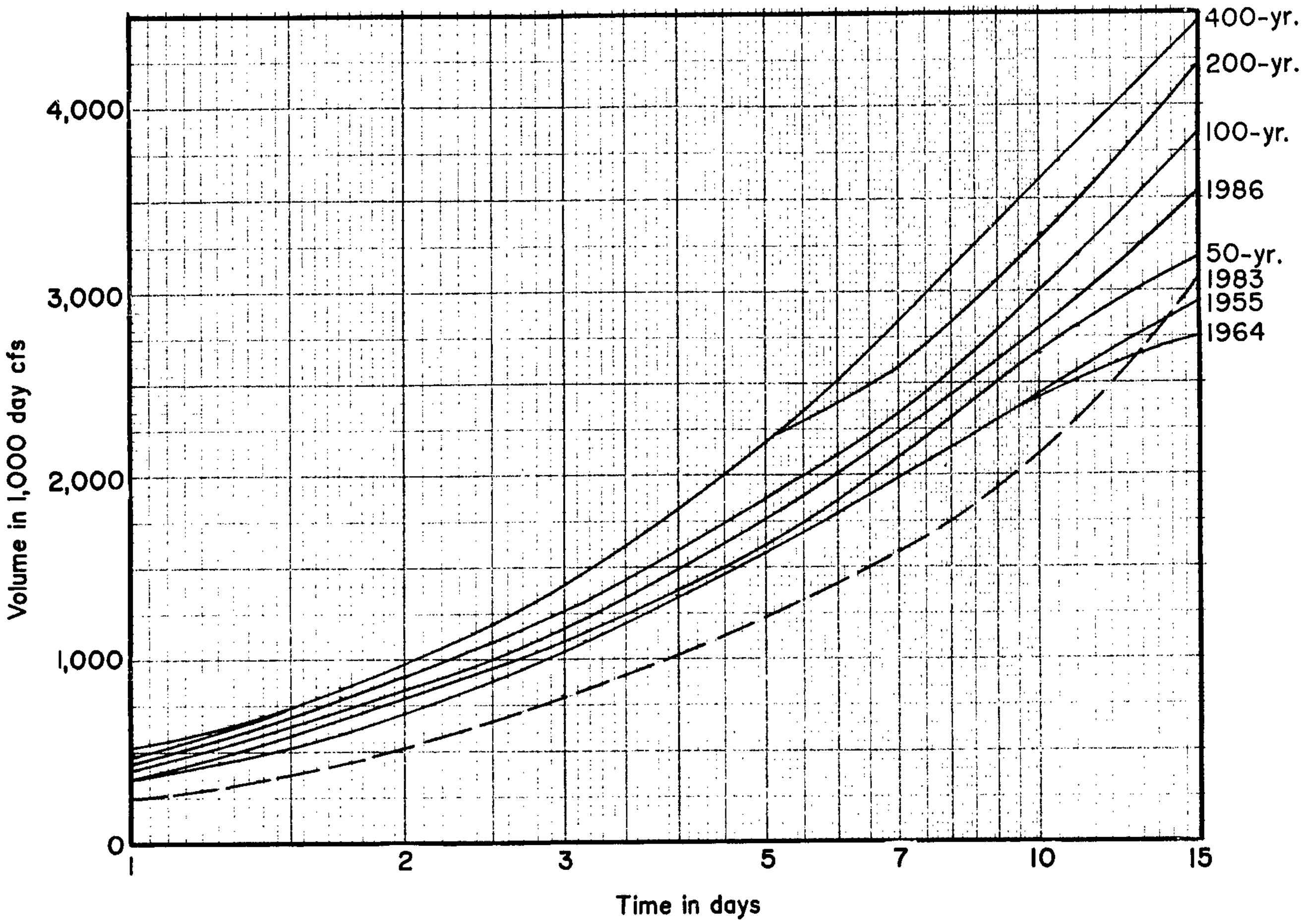
SACRAMENTO AND FEATHER RIVER CONFLUENCE

CORPS OF ENGINEERS, SACRAMENTO, CALIFORNIA

Prepared: R.F.C.
Drawn: C.A.P.

Date: JANUARY 1990

CHART 11



NOTE:
The 2 and 4 hundred year curves reflect upstream levee failure.

AMERICAN RIVER AND SACRAMENTO METRO INVESTIGATIONS, CALIFORNIA

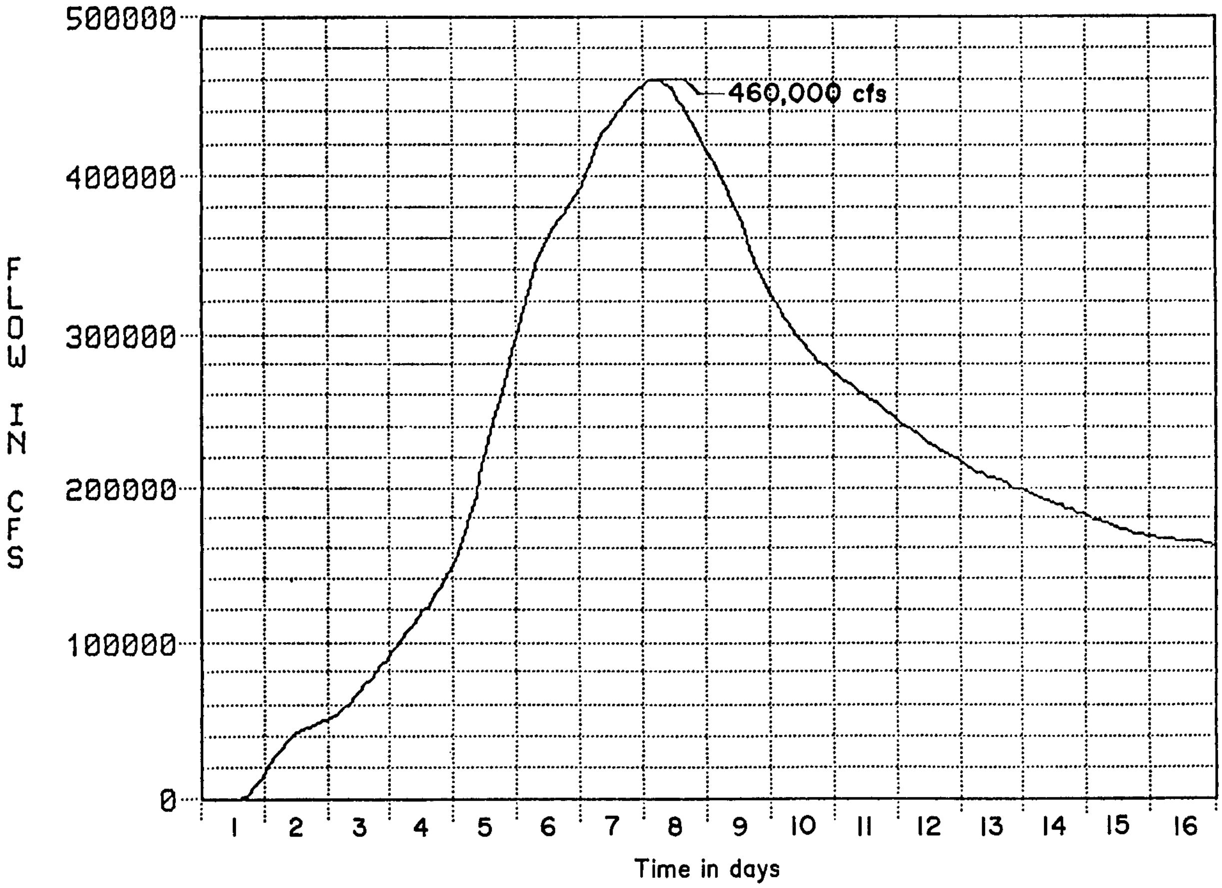
FLOOD VOLUME MASS CURVES

SACRAMENTO AND FEATHER RIVER CONFLUENCE

CORPS OF ENGINEERS, SACRAMENTO, CALIFORNIA

Prepared: R.F.C.
Drawn: C.A.P.
Date: JANUARY 1990

CHART 12



AMERICAN RIVER AND SACRAMENTO
METRO INVESTIGATIONS, CALIFORNIA

100-YEAR FLOOD HYDROGRAPH

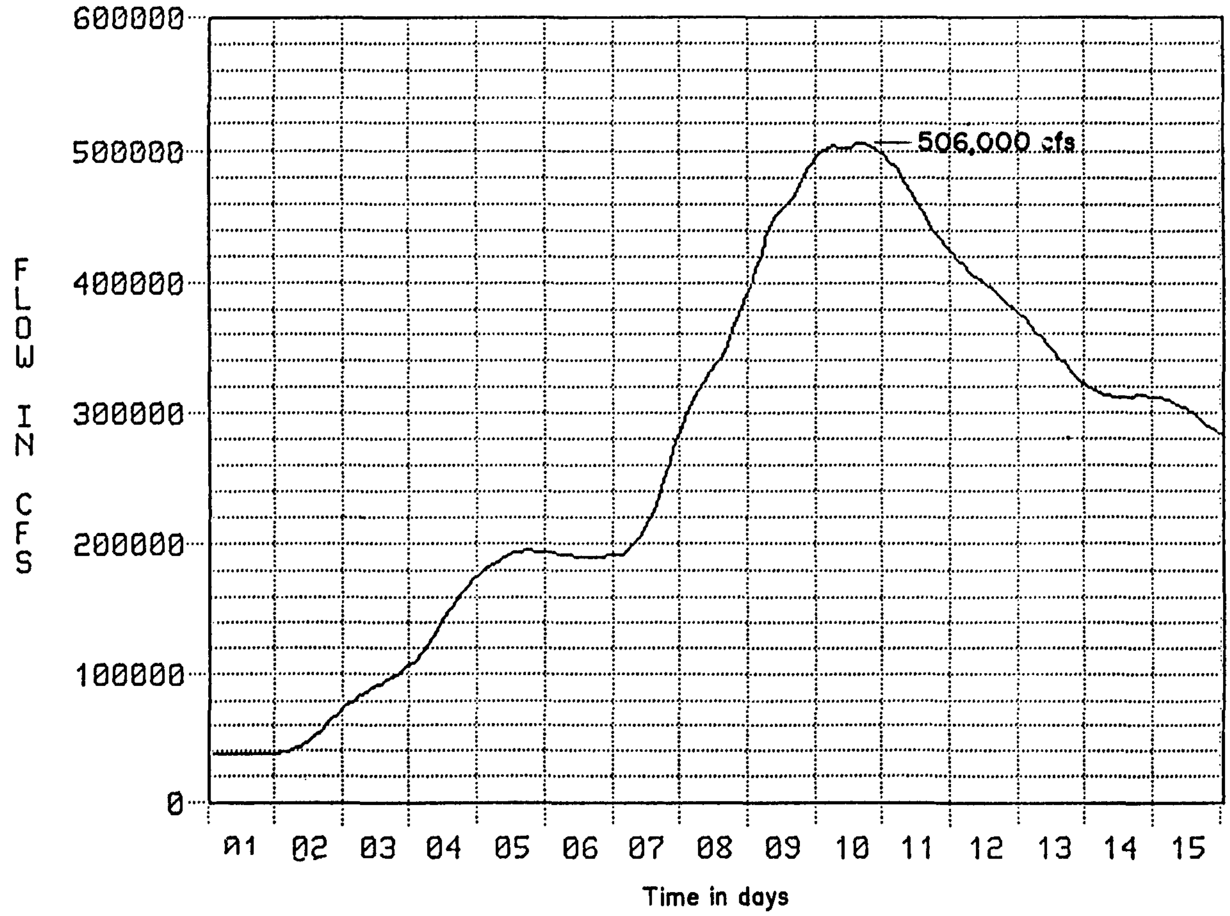
SACRAMENTO AND FEATHER RIVER
CONFLUENCE

CORPS OF ENGINEERS. SACRAMENTO. CALIFORNIA

Prepared : R.F.C.
Drawn : C.A.P.

Date : JANUARY 1990

CHART 13



AMERICAN RIVER AND SACRAMENTO
METRO INVESTIGATIONS, CALIFORNIA

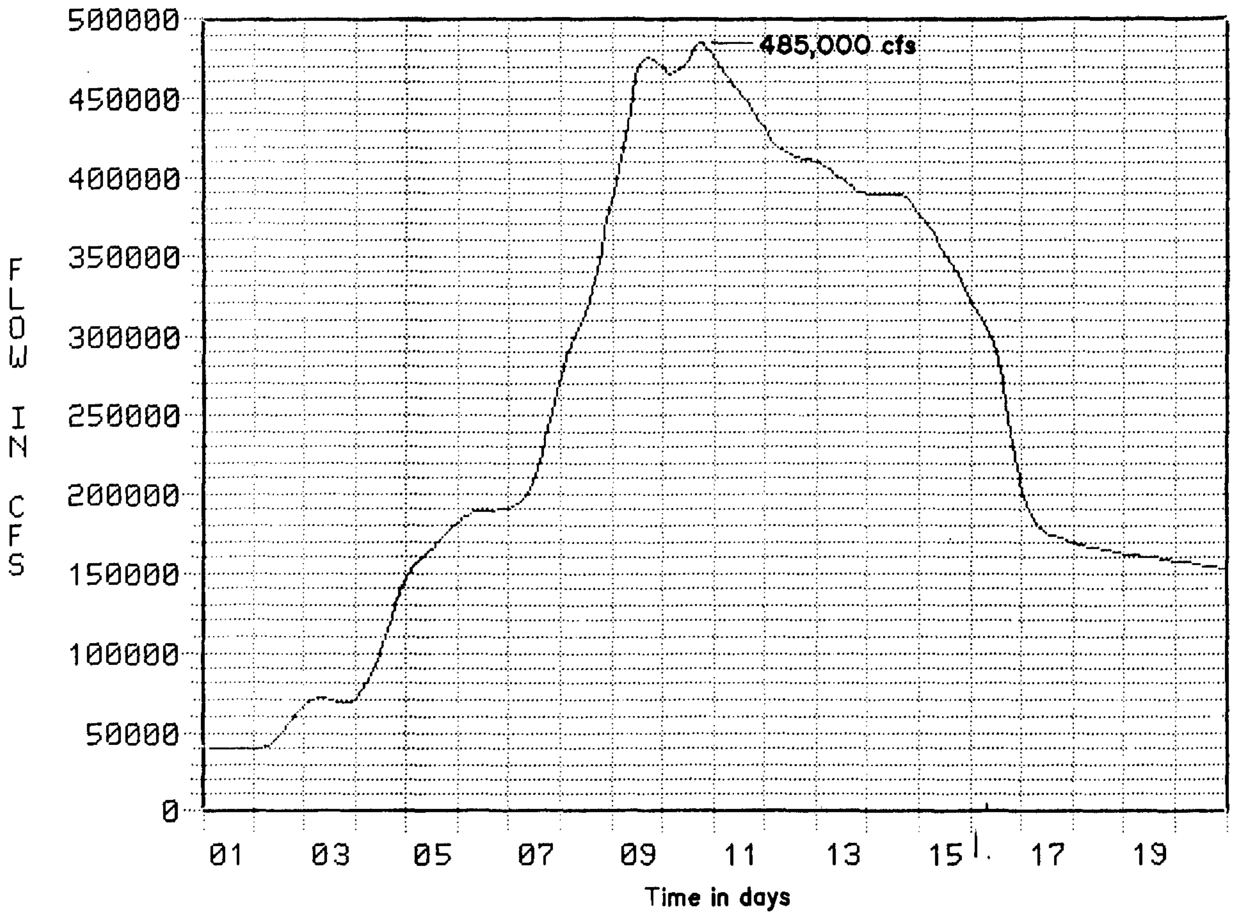
400-YEAR FLOOD HYDROGRAPH

SACRAMENTO AND FEATHER RIVER
CONFLUENCE

CORPS OF ENGINEERS. SACRAMENTO. CALIFORNIA

Prepared : R.F.C.
Drawn : C.A.P.
Date : JANUARY 1990

CHART 14



AMERICAN RIVER AND SACRAMENTO
METRO INVESTIGATIONS, CALIFORNIA

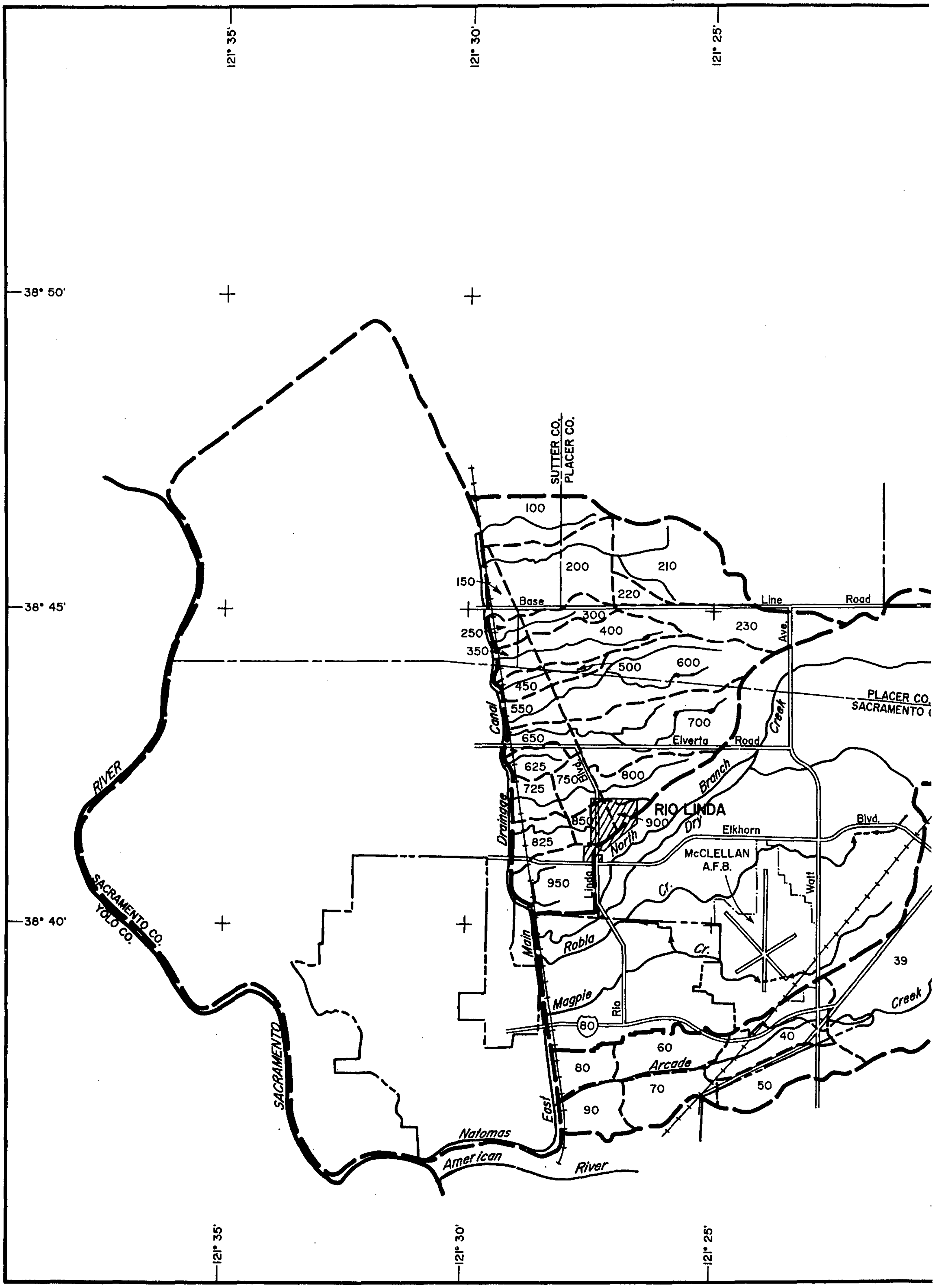
200-YEAR FLOOD HYDROGRAPH

SACRAMENTO AND FEATHER RIVER
CONFLUENCE

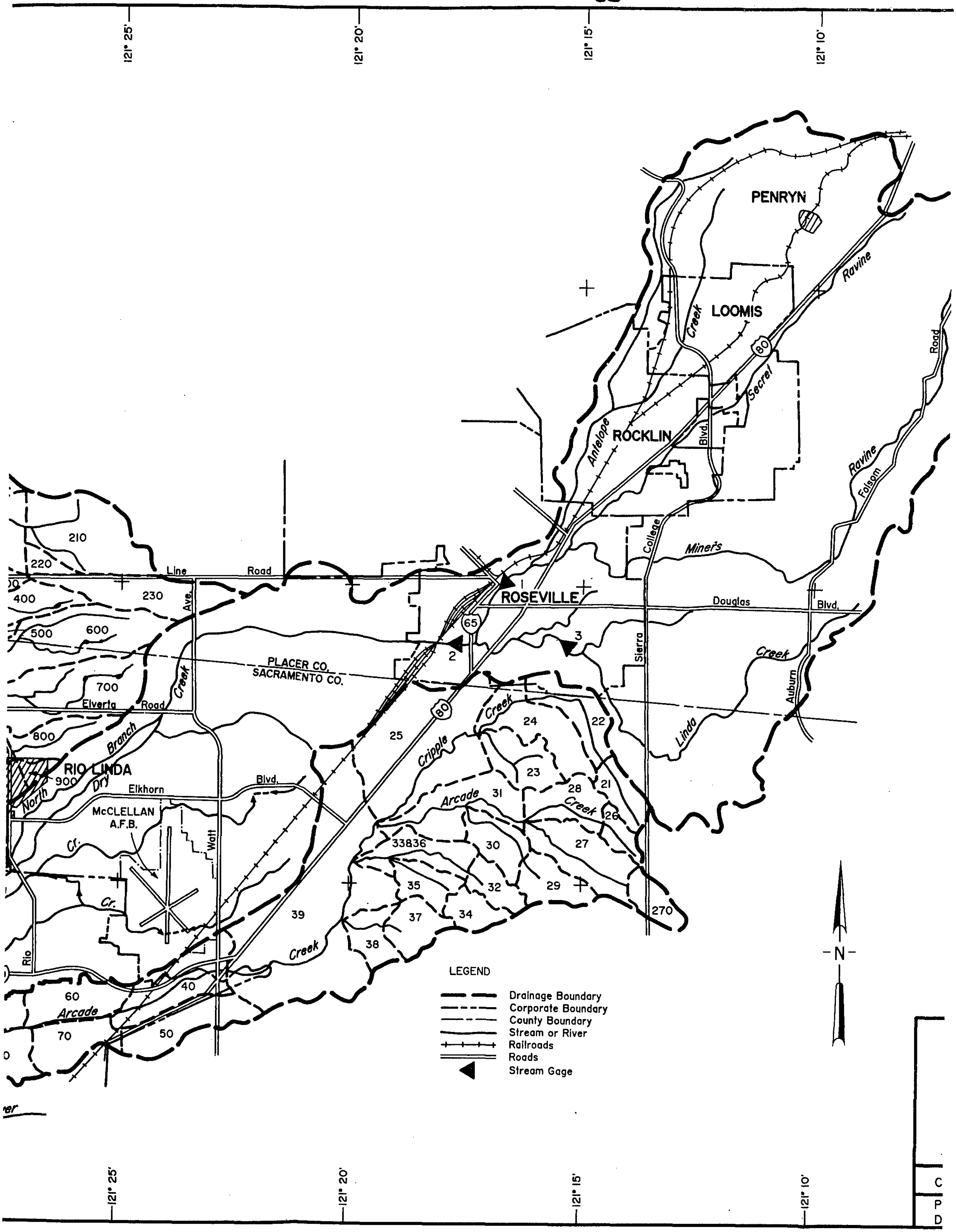
CORPS OF ENGINEERS. SACRAMENTO. CALIFORNIA

Prepared: R.F.C.
Drawn: C.A.P.
Date: JANUARY 1990

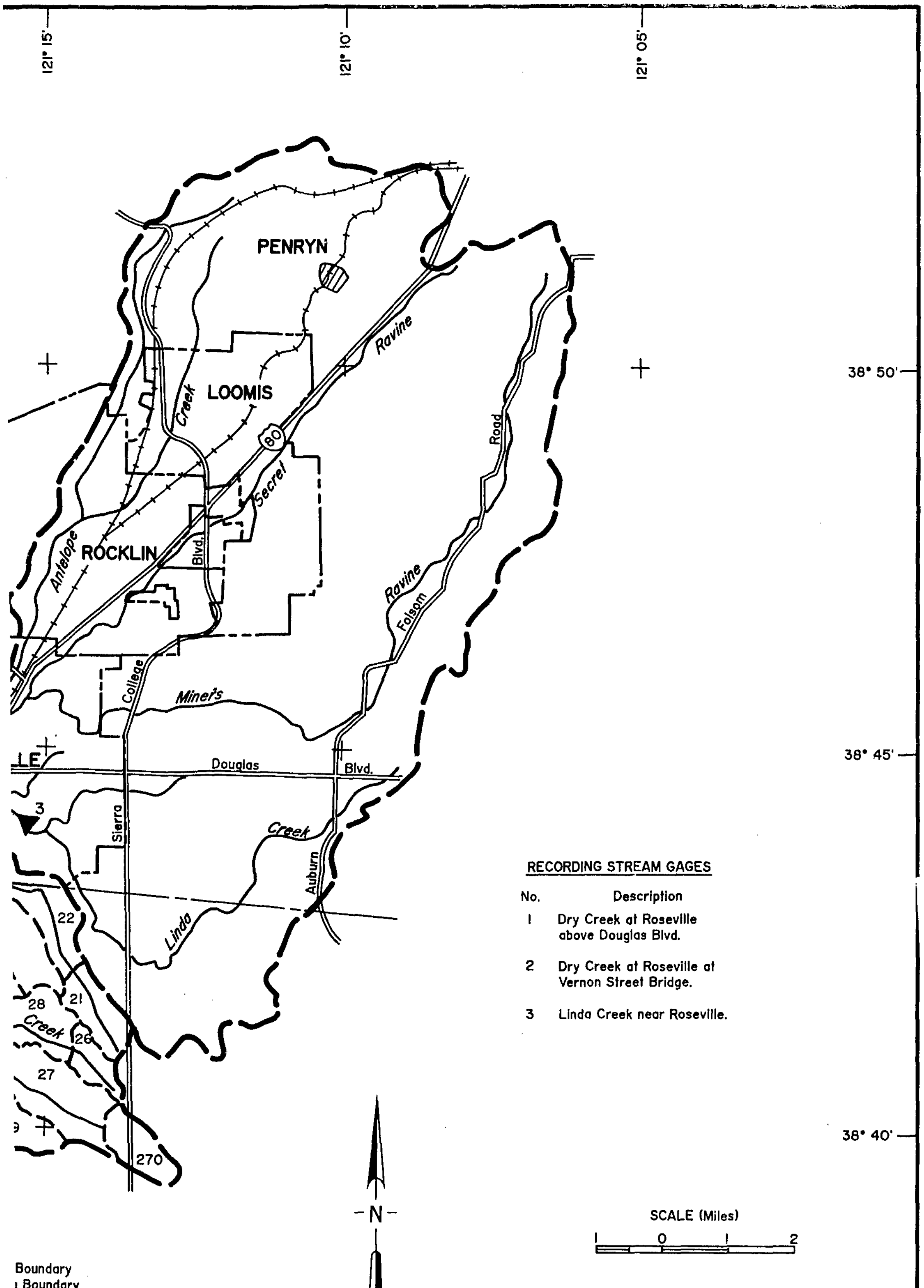
CHART 15



121° 35'
121° 30'
121° 25'
38° 50'
38° 45'
38° 40'
SUTTER CO.
PLACER CO.
PLACER CO.
SACRAMENTO
100
200
210
150
220
Base
Line
Road
300
400
230
250
350
Ave.
500
600
450
550
Canal
700
650
Elverta
Road
Creek
625
750
Blvd.
800
725
Branch
RIO LINDA
Drainage
850
900
Dry
North
825
Elkhorn
Blvd.
McCLELLAN
A.F.B.
950
Linda
Cr.
Watt
Robla
Cr.
Main
39
Magpie
Rio
80
Creek
60
40
80
Arcade
70
50
90
East
Natomas
American
River
RIVER
SACRAMENTO CO.
YOLO CO.
SACRAMENTO


121° 25'
121° 20'
121° 15'
121° 10'
PENRYN
LOOMIS
ROCKLIN
ROSEVILLE
RIO LINDA
McCLELLAN A.F.B.
PLACER CO.
SACRAMENTO CO.
Line Road
Douglas Blvd.
Elverta Road
Elkhorn Blvd.
Watt Ave.
Sierra College Blvd.
Auburn Folsom Road
Rio
Antelope Creek
Secret Ravine
Miner's Ravine
Linda Creek
Cripple Creek
Arcade Creek
North Branch Dry Creek
Cr.
Cr.
Creek
Arcade
80
65
1
2
3
210
220
230
400
500
600
700
800
900
21
22
23
24
25
26
27
28
29
30
31
32
33836
34
35
37
38
39
40
50
60
70
270
LEGEND
Drainage Boundary
Corporate Boundary
County Boundary
Stream or River
Railroads
Roads
Stream Gage
N
C
P
D

3



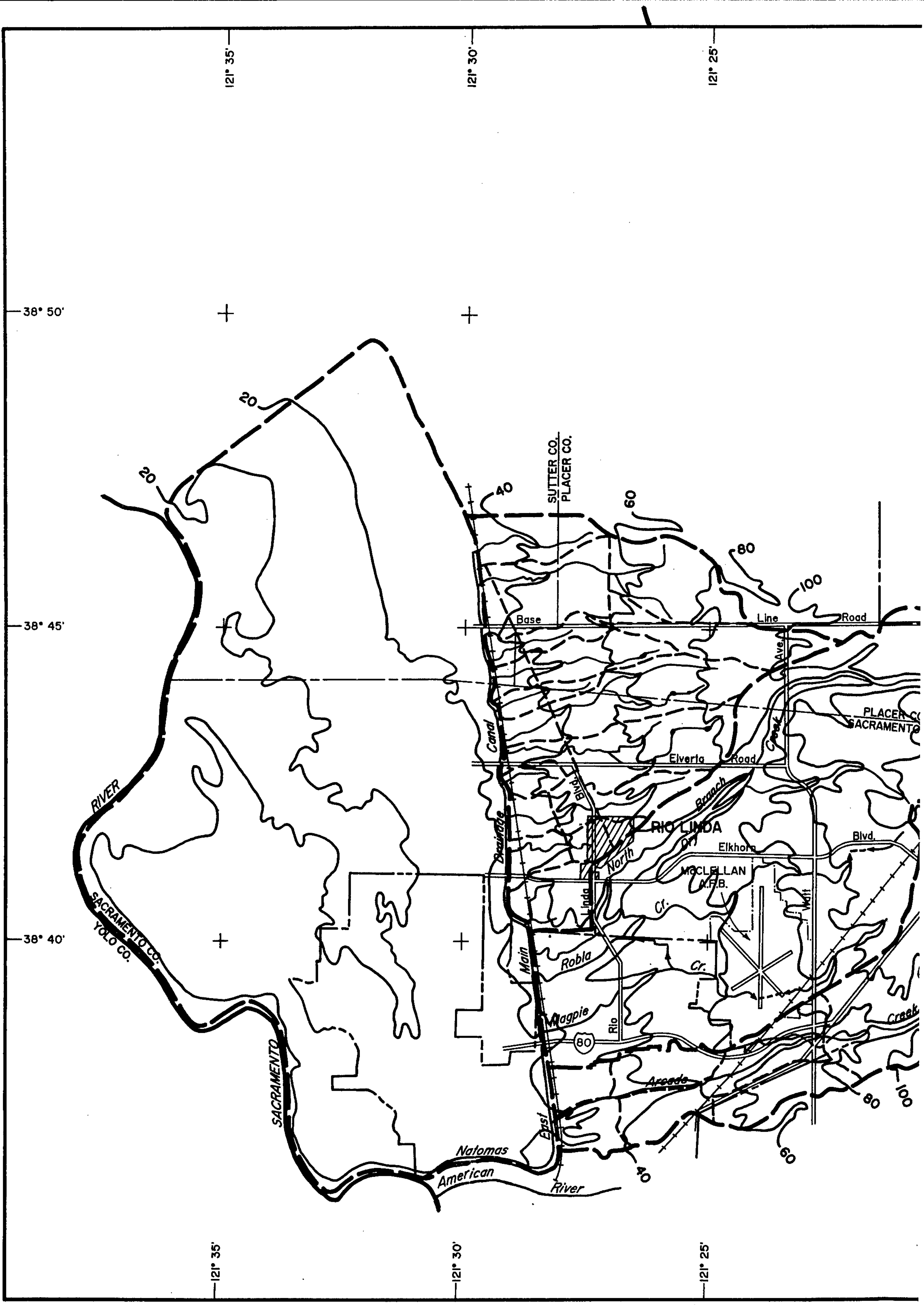
AMERICAN RIVER AND SACRAMENTO
METRO INVESTIGATIONS, CALIFORNIA

DRY, ARCADE AND ELVERTA DRAINAGE SUBAREA MAP

CORPS OF ENGINEERS SACRAMENTO, CALIFORNIA

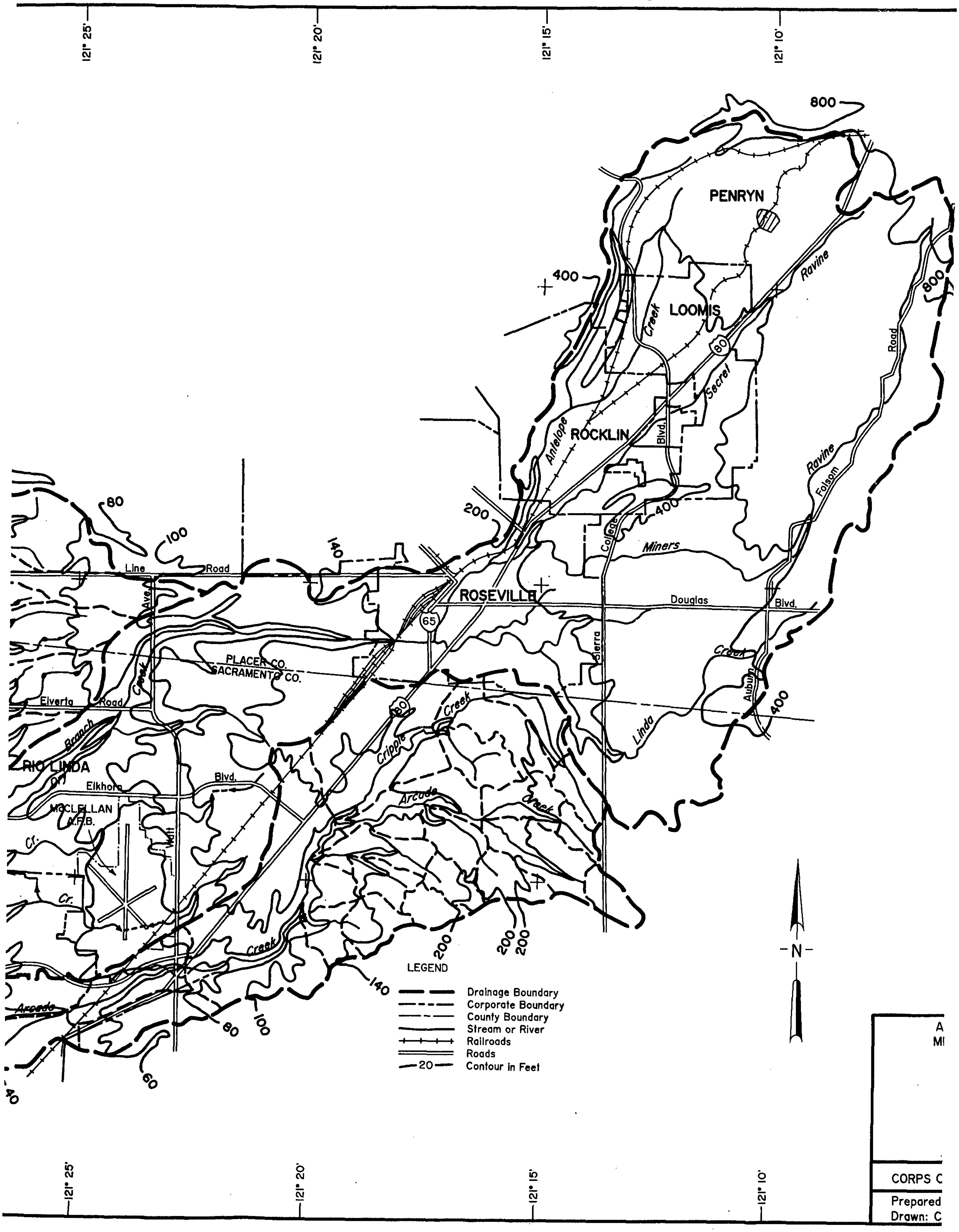
Prepared: J.H.
Drawn: C.A.P.
Date: JAN 1990

CHART 16

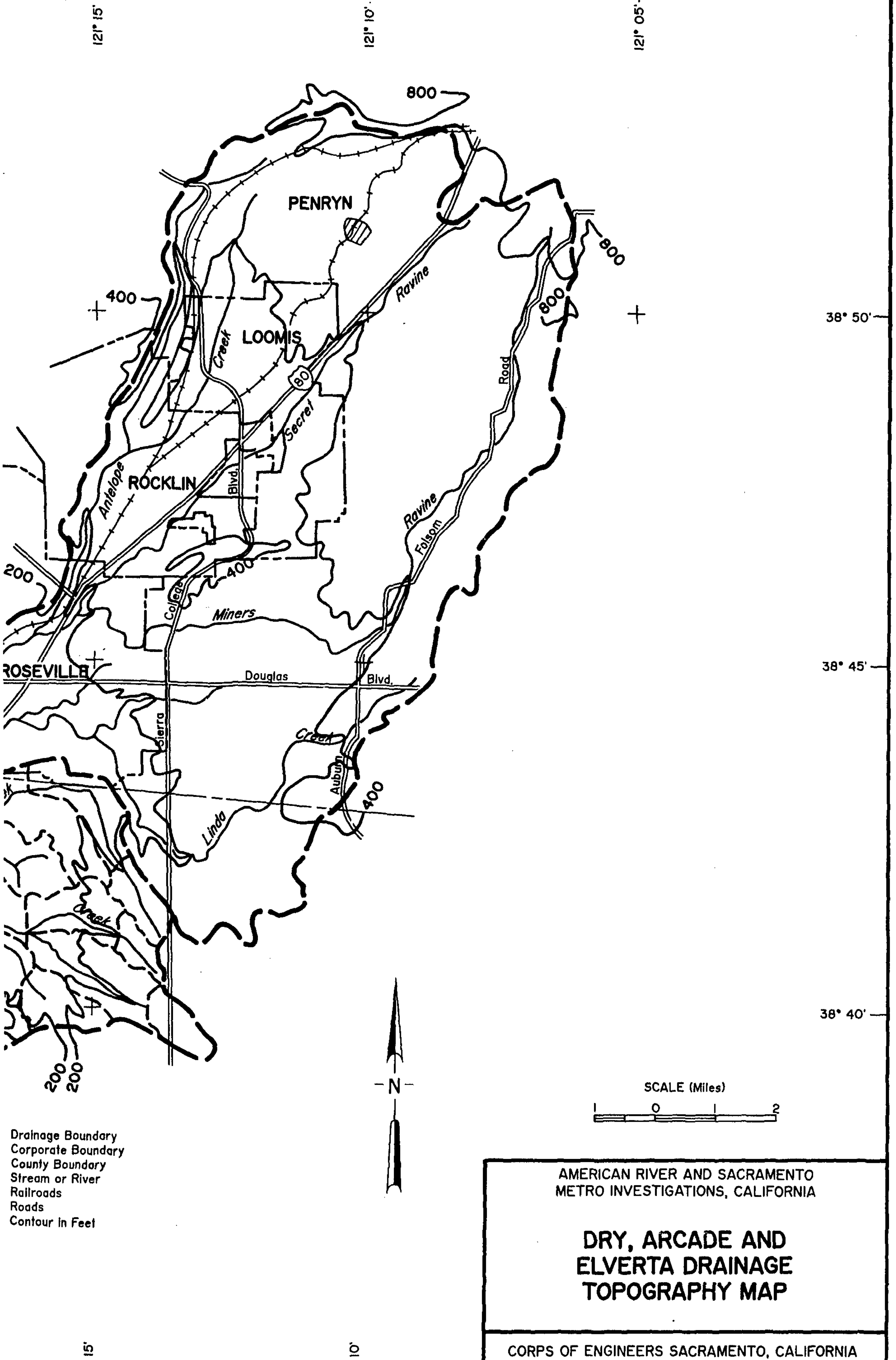


121° 35'
121° 30'
121° 25'
38° 50'
38° 45'
38° 40'
20
20
40
60
80
100
SUTTER CO.
PLACER CO.
Base
Line
Road
Ave.
PLACER CO.
SACRAMENTO
Canal
Drainage
Main
East
Elverta
Road
Creek
Blvd.
Branch
North
Dry
RIO LINDA
Elkhorn
Blvd.
McCLELLAN
A.F.B.
Linda
Rio
Cr.
Watt
Robla
Cr.
Magpie
80
Creek
Arcade
RIVER
SACRAMENTO CO.
YOLO CO.
SACRAMENTO
Natomas
American
River
80
100
60
40

2



121° 25'
121° 20'
121° 15'
121° 10'
PENRYN
LOOMIS
ROCKLIN
ROSEVILLE
RIO LINDA
McCLELLAN A.F.B.
PLACER CO.
SACRAMENTO CO.
Line Road
Elverta Road
Elkhorn Blvd.
Douglas Blvd.
Folsom Road
Auburn
Sierra
College
Blvd.
Watt
Ave.
Antelope Creek
Secret Ravine
Miners Ravine
Linda Creek
Cripple Creek
Arcade Creek
Dry Creek
Branch
Cr.
Creek
80
65
800
400
200
140
100
80
60
40
LEGEND
Drainage Boundary
Corporate Boundary
County Boundary
Stream or River
Railroads
Roads
20 Contour in Feet
N
A
MI
CORPS C
Prepared
Drawn: C



AMERICAN RIVER AND SACRAMENTO
METRO INVESTIGATIONS, CALIFORNIA

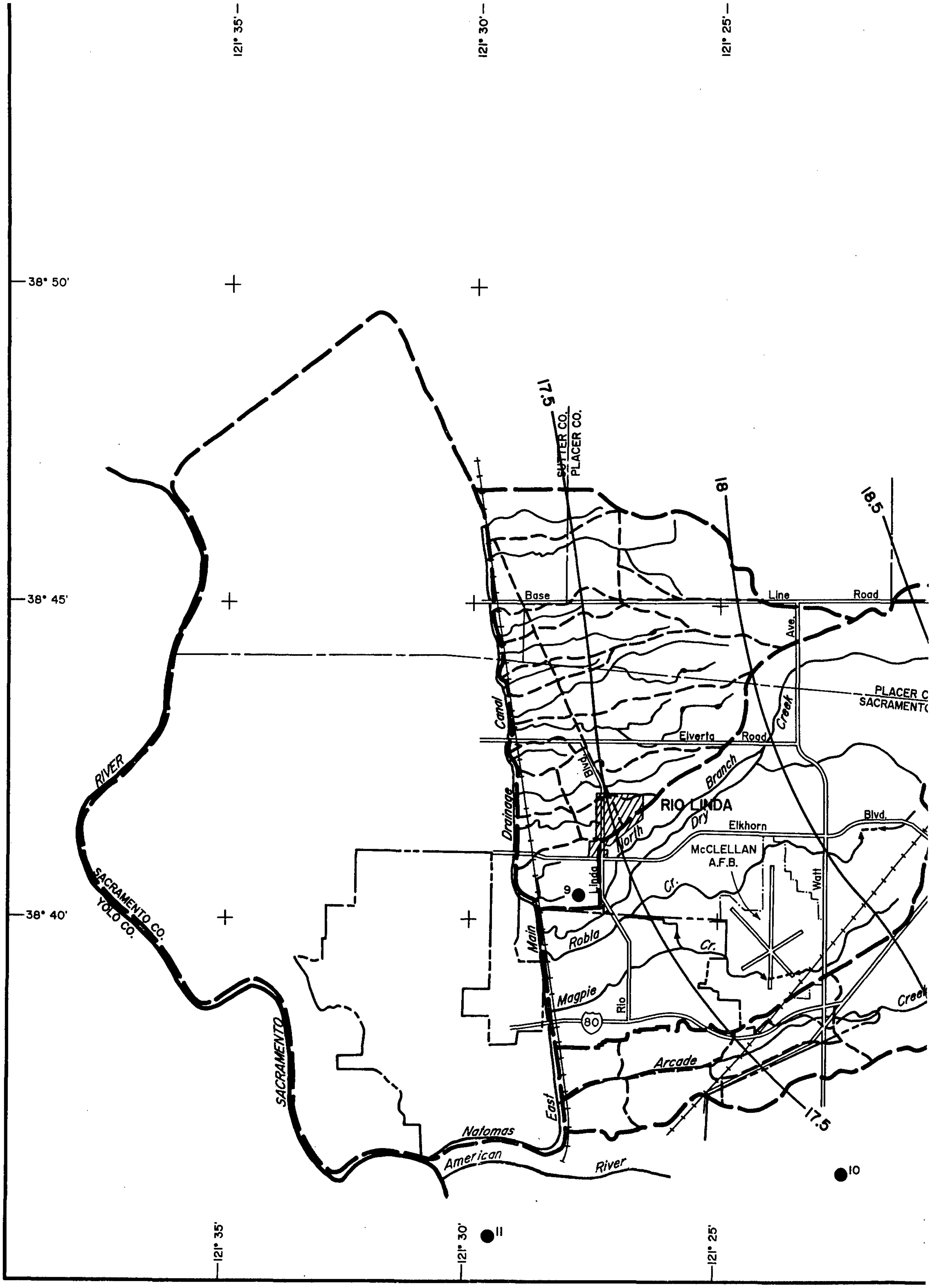
DRY, ARCADE AND ELVERTA DRAINAGE TOPOGRAPHY MAP

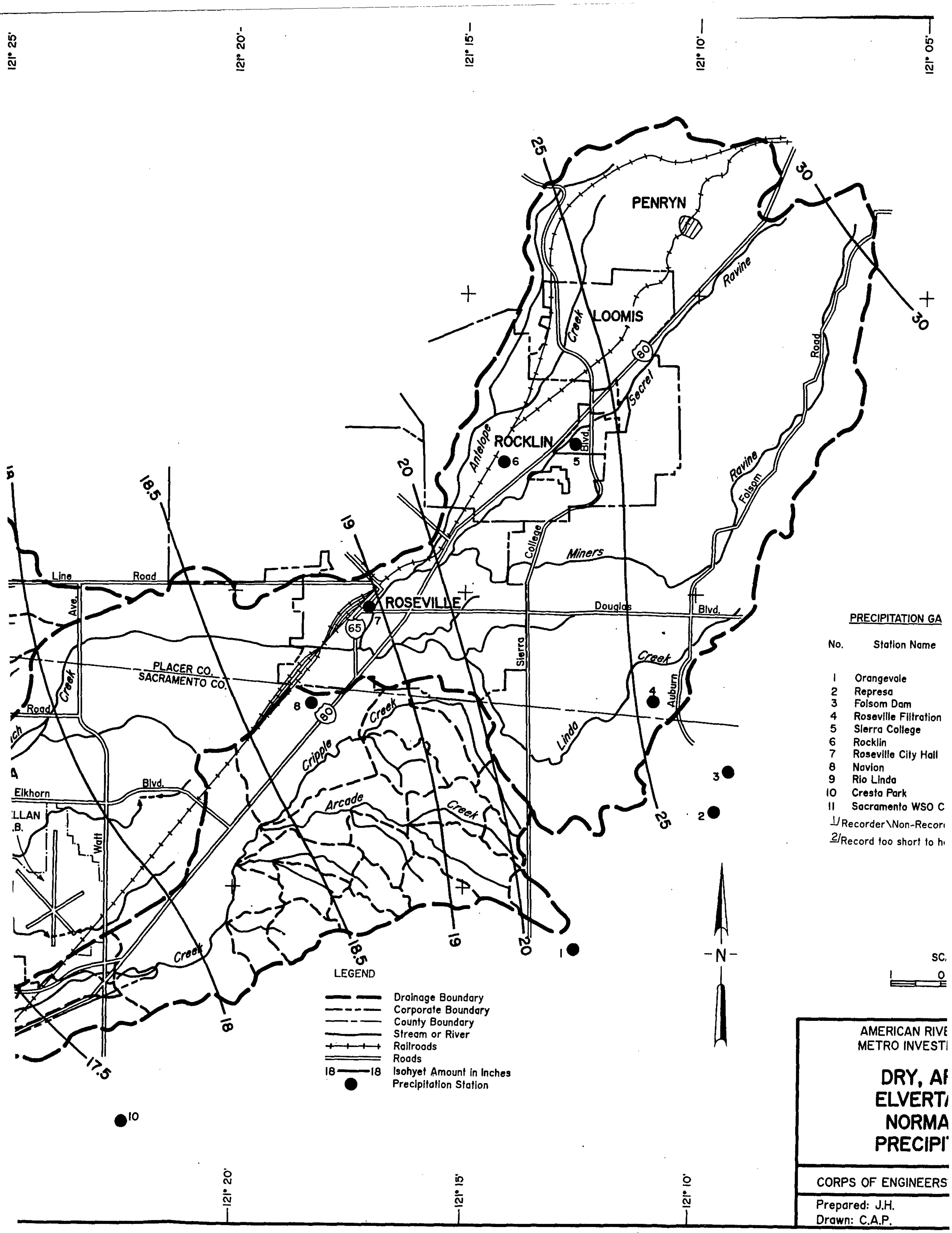
CORPS OF ENGINEERS SACRAMENTO, CALIFORNIA

Prepared: J.H.
Drawn: C.A.P.

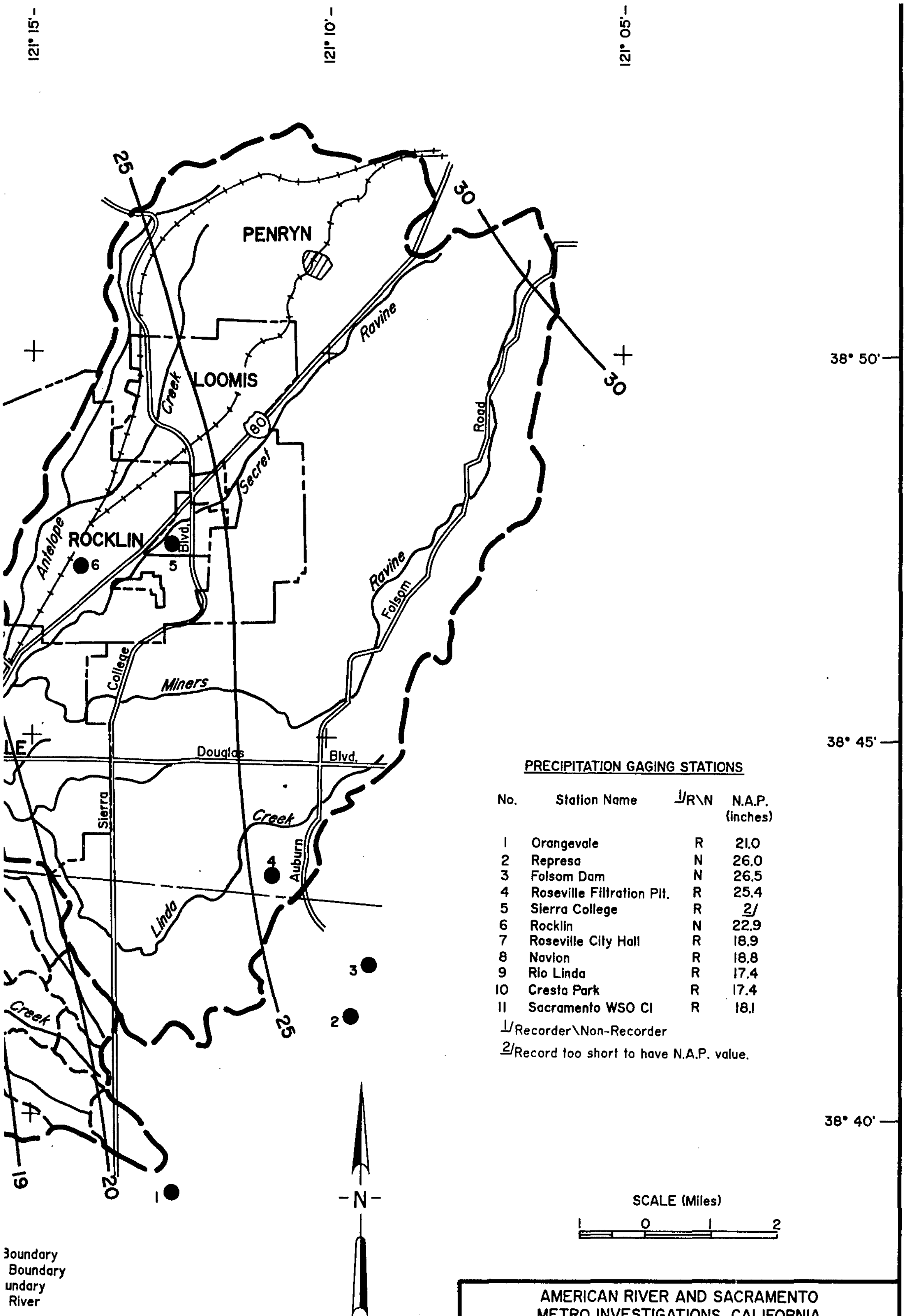
Date: JAN 1990

CHART 17


121° 35'
121° 30'
121° 25'
38° 50'
38° 45'
38° 40'
17.5
SUTTER CO.
PLACER CO.
18
18.5
Base
Line
Road
Ave.
PLACER C
SACRAMENTO
Canal
Elverta
Road
Creek
Blvd.
Branch
RIO LINDA
Dry
North
Elkhorn
Blvd.
Drainage
McCLELLAN
A.F.B.
Watt
9
Linda
Cr.
RIVER
SACRAMENTO CO.
YOLO CO.
Main
Robla
Cr.
Magpie
Rio
80
Creek
SACRAMENTO
Arcade
East
17.5
Natomas
American
River
10
11



121° 25'
121° 20'
121° 15'
121° 10'
121° 05'
PENRYN
LOOMIS
ROCKLIN
ROSEVILLE
Antelope
Creek
Secret
Ravine
Road
Folsom
Blvd.
College
Miners
Line
Road
Douglas
Blvd.
Ave.
PLACER CO.
SACRAMENTO CO.
Sierra
Creek
Auburn
Linda
Cripple
Creek
Arcade
Creek
Elkhorn
Blvd.
Watt
Road
80
65
25
30
20
18.5
19
18
17.5
PRECIPITATION GA
No.
Station Name
1 Orangevale
2 Represa
3 Folsom Dam
4 Roseville Filtration
5 Sierra College
6 Rocklin
7 Roseville City Hall
8 Navion
9 Rio Linda
10 Cresta Park
11 Sacramento WSO C
1/Recorder\Non-Recor
2/Record too short to h
LEGEND
Drainage Boundary
Corporate Boundary
County Boundary
Stream or River
Railroads
Roads
18——18 Isohyet Amount in Inches
Precipitation Station
N
SC.
0
AMERICAN RIVE
METRO INVESTI
DRY, AI
ELVERT
NORMA
PRECIPI
CORPS OF ENGINEERS
Prepared: J.H.
Drawn: C.A.P.



PRECIPITATION GAGING STATIONS

No.	Station Name	1/R\N	N.A.P. (inches)
1	Orangevale	R	21.0
2	Represa	N	26.0
3	Folsom Dam	N	26.5
4	Roseville Filtration Plt.	R	25.4
5	Sierra College	R	2/
6	Rocklin	N	22.9
7	Roseville City Hall	R	18.9
8	Navion	R	18.8
9	Rio Linda	R	17.4
10	Cresta Park	R	17.4
11	Sacramento WSO CI	R	18.1

1/ Recorder\Non-Recorder
2/ Record too short to have N.A.P. value.

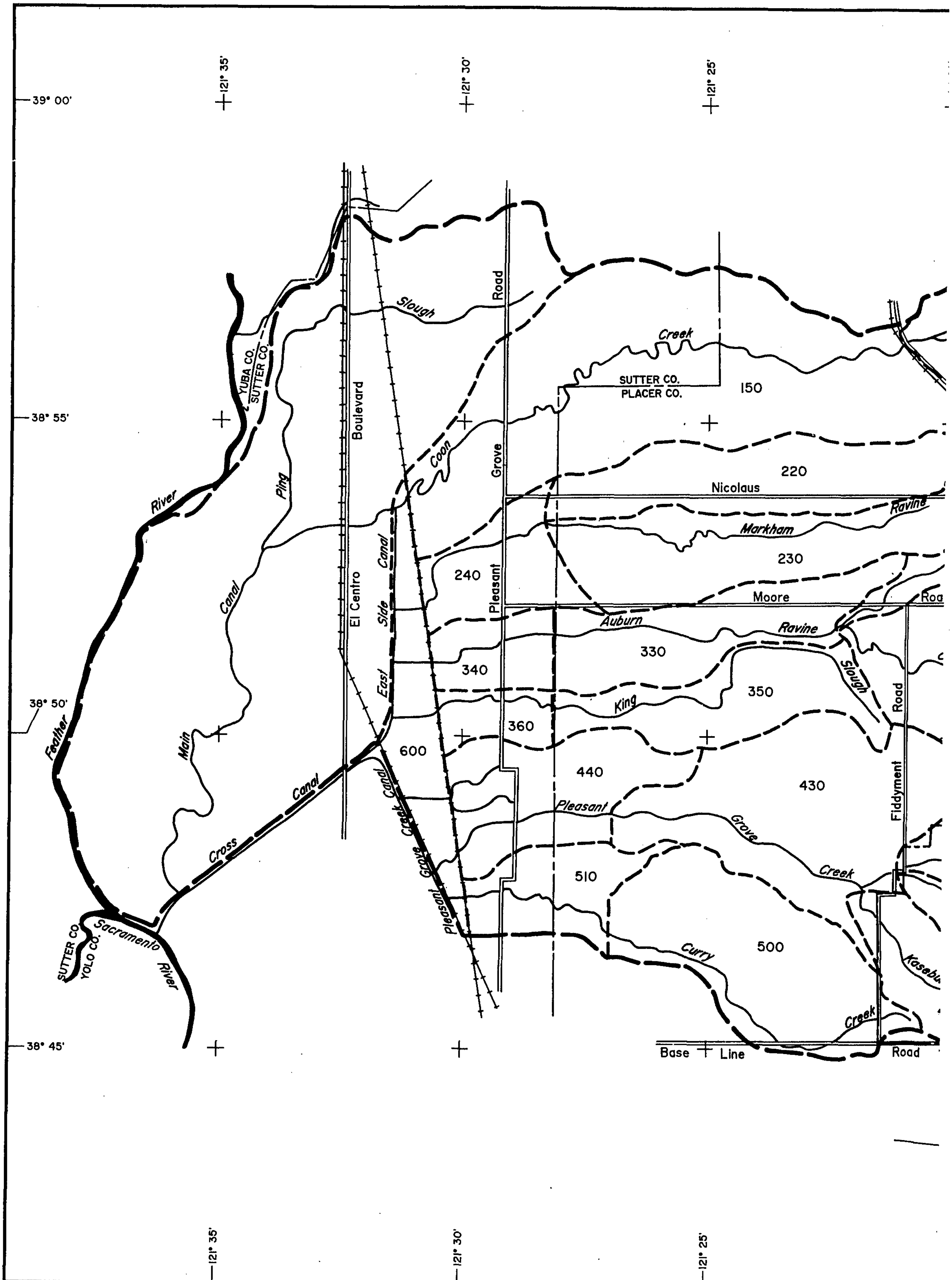
AMERICAN RIVER AND SACRAMENTO
METRO INVESTIGATIONS, CALIFORNIA

DRY, ARCADE AND ELVERTA DRAINAGE NORMAL ANNUAL PRECIPITATION MAP

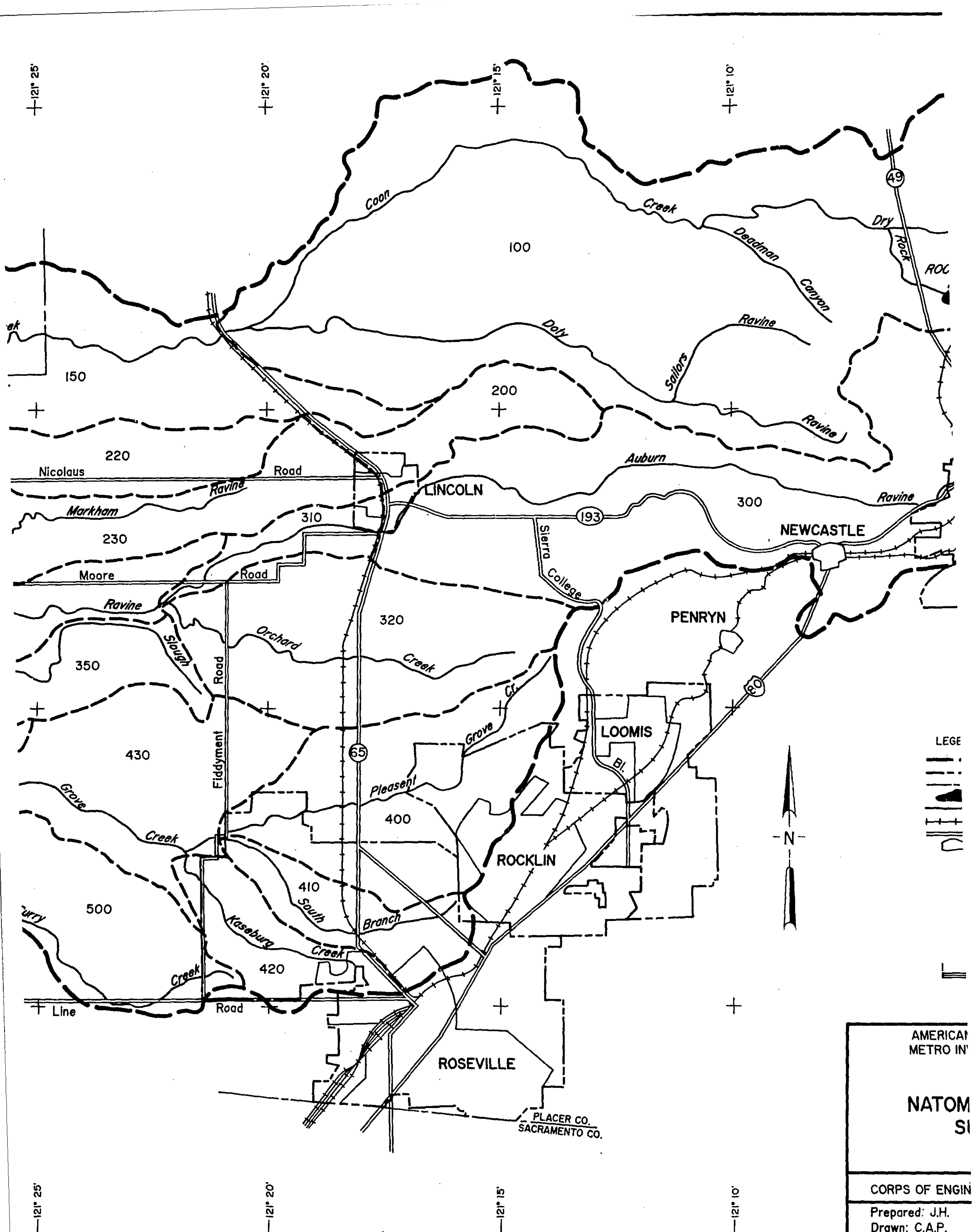
CORPS OF ENGINEERS SACRAMENTO, CALIFORNIA

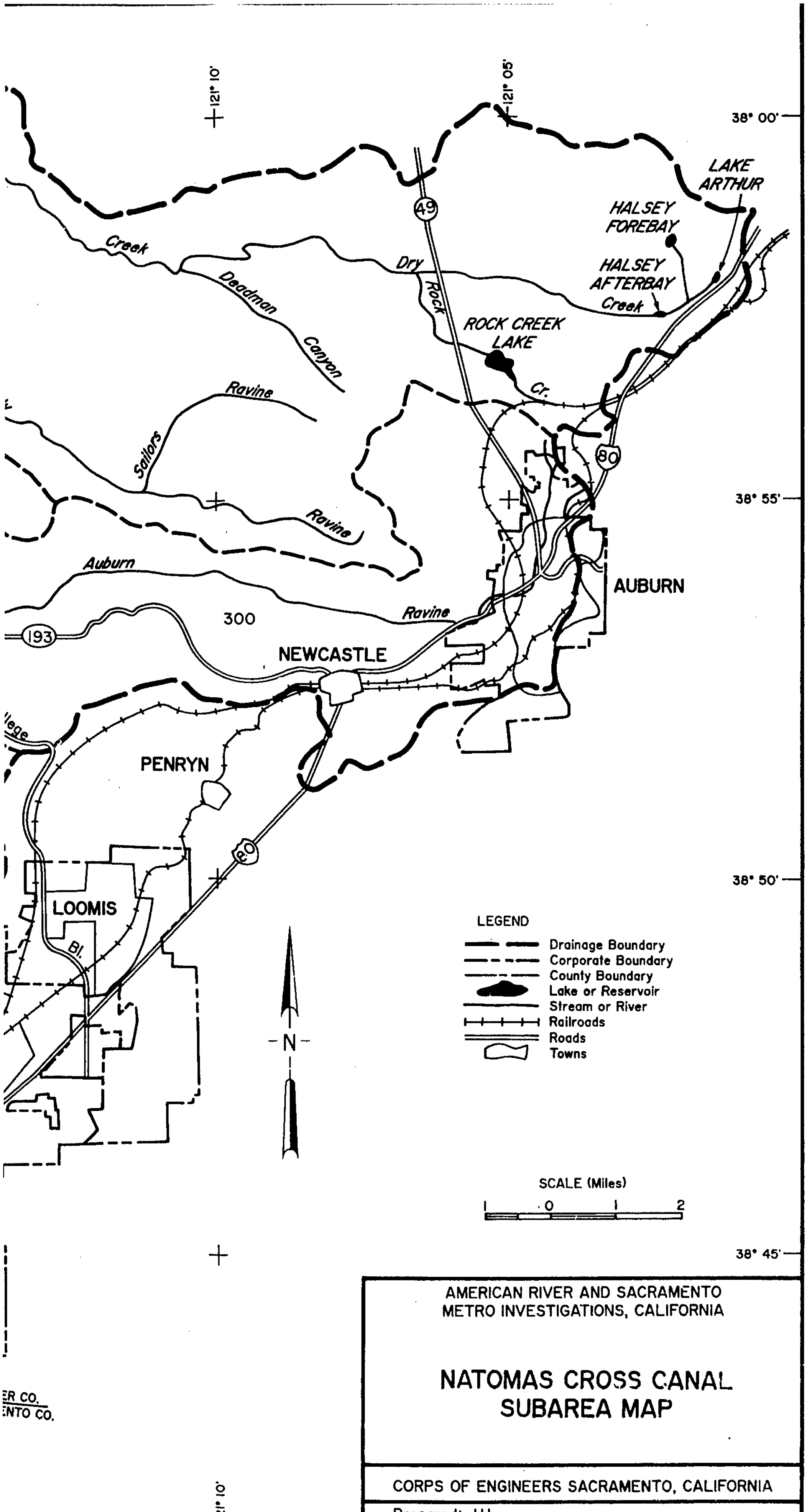
Prepared: J.H.
Drawn: C.A.P.
Date: JAN 1990

CHART 18


39° 00'
38° 55'
38° 50'
38° 45'
121° 35'
121° 30'
121° 25'
YUBA CO.
SUTTER CO.
PLACER CO.
YOLO CO.
Feather River
Sacramento River
Slough
Road
Creek
Boulevard
El Centro
Ping
Main Canal
Cross Canal
Coon Creek
Pleasant Grove
Pleasant Grove Creek Canal
East Side Canal
Nicolaus
Markham Ravine
Moore Road
Auburn Ravine
King Slough
Fiddyment Road
Pleasant Grove Creek
Curry Creek
Base Line Road
150
220
230
240
330
340
350
360
430
440
500
510
600

1


121° 25'
121° 20'
121° 15'
121° 10'
49
Coon
Creek
Dry
Rock
Deadman
Canyon
100
Doty
Ravine
Sailors
Ravine
150
200
220
Nicolaus
Road
Ravine
Auburn
Markham
LINCOLN
300
Ravine
310
193
230
NEWCASTLE
Sierra
College
Moore
Road
Ravine
PENRYN
320
Orchard
Slough
Creek
350
Road
Cr.
80
Grove
LOOMIS
430
Fiddyment
65
Bl.
LEGE
Pleasent
Grove
400
Creek
N
ROCKLIN
410
South
Branch
500
Kaseburg
Creek
420
Creek
Line
Road
ROSEVILLE
AMERICAN
METRO IN
PLACER CO.
SACRAMENTO CO.
NATOM
SI
CORPS OF ENGIN
Prepared: J.H.
Drawn: C.A.P.



AMERICAN RIVER AND SACRAMENTO
METRO INVESTIGATIONS, CALIFORNIA

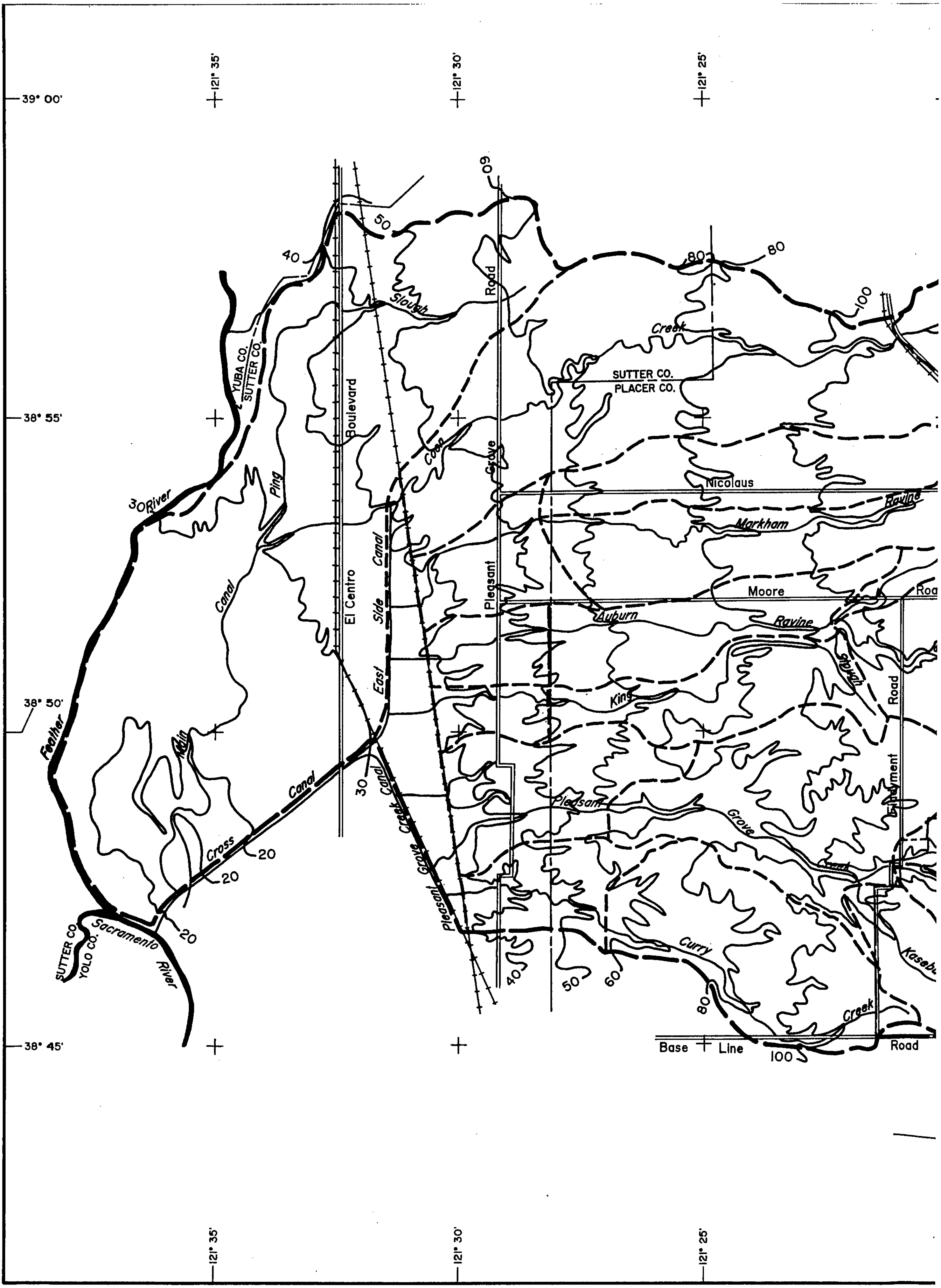
NATOMAS CROSS CANAL SUBAREA MAP

CORPS OF ENGINEERS SACRAMENTO, CALIFORNIA

Prepared: J.H.
Drawn: C.A.P.

Date: JAN 1990

CHART 19



39° 00'
38° 55'
38° 50'
38° 45'
121° 35'
121° 30'
121° 25'
YUBA CO.
SUTTER CO.
SUTTER CO.
PLACER CO.
SUTTER CO.
YOLO CO.
Feather
River
Sacramento
River
Slough
Creek
Coon
Boulevard
El Centro
Ping
Canal
East
Side
Canal
Cross
Canal
Pleasant
Grove
Road
Nicolaus
Markham
Ravine
Moore
Auburn
Ravine
King
Slough
Pleasant
Grove
Creek
Canal
Curry
Creek
Base
Line
Road
Kaseberg
Pleasant Grove Creek Canal
Road
Pleasant Grove
Road
20
20
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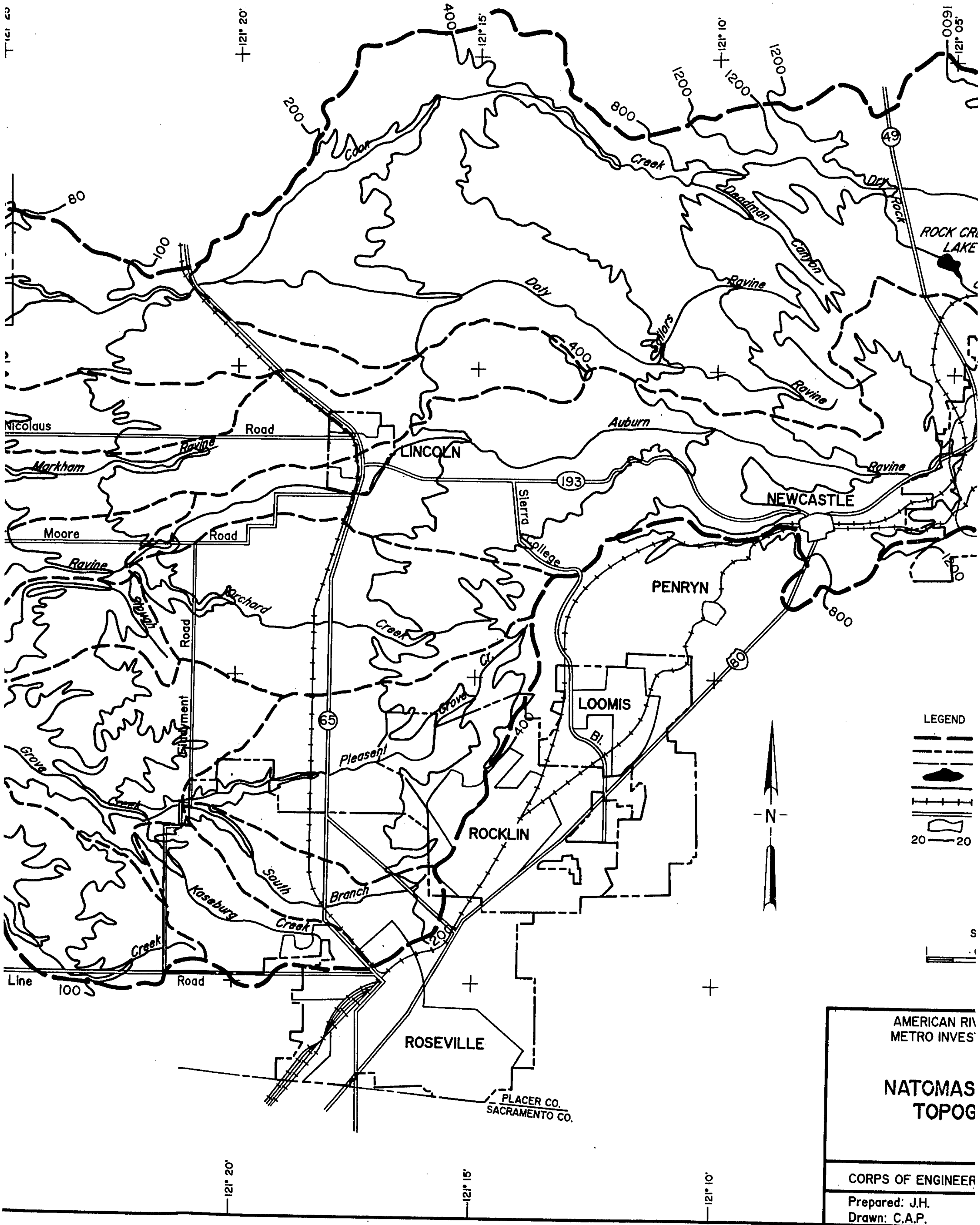
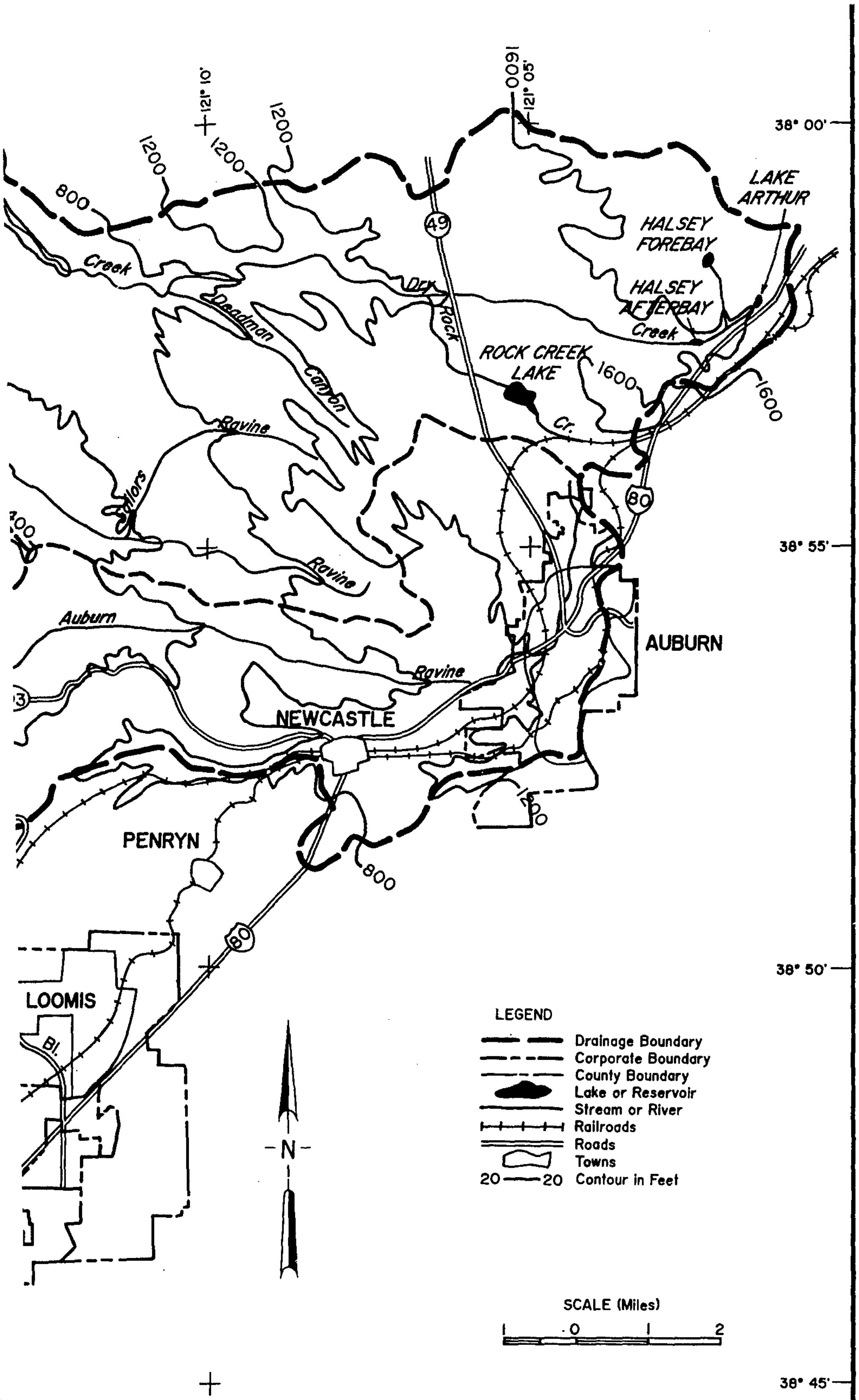
80
80
80
100
100



121° 20'
121° 15'
121° 10'
121° 05'
400
200
1200
800
1600
80
100
Coon
Creek
Deadman
Canyon
Dry
Rock
ROCK CR
LAKE
Doty
Ravine
Sailors
Auburn
Nicolaus
Road
Markham
LINCOLN
193
Sierra
College
NEWCASTLE
49
Moore
Road
Ravine
Orchard
Creek
Cr.
Grove
PENRYN
800
80
LOOMIS
Bl.
65
Pleasent
Grove
Road
Sunrise
Industrial
Creek
ROCKLIN
South
Branch
Kaseburg
Creek
Creek
Line
Road
100
200
ROSEVILLE
PLACER CO.
SACRAMENTO CO.
LEGEND
20
20
N
AMERICAN RI
METRO INVES
NATOMAS
TOPOG
CORPS OF ENGINEER
Prepared: J.H.
Drawn: C.A.P.



AMERICAN RIVER AND SACRAMENTO
METRO INVESTIGATIONS, CALIFORNIA

NATOMAS CROSS CANAL
TOPOGRAPHY MAP

CORPS OF ENGINEERS SACRAMENTO, CALIFORNIA

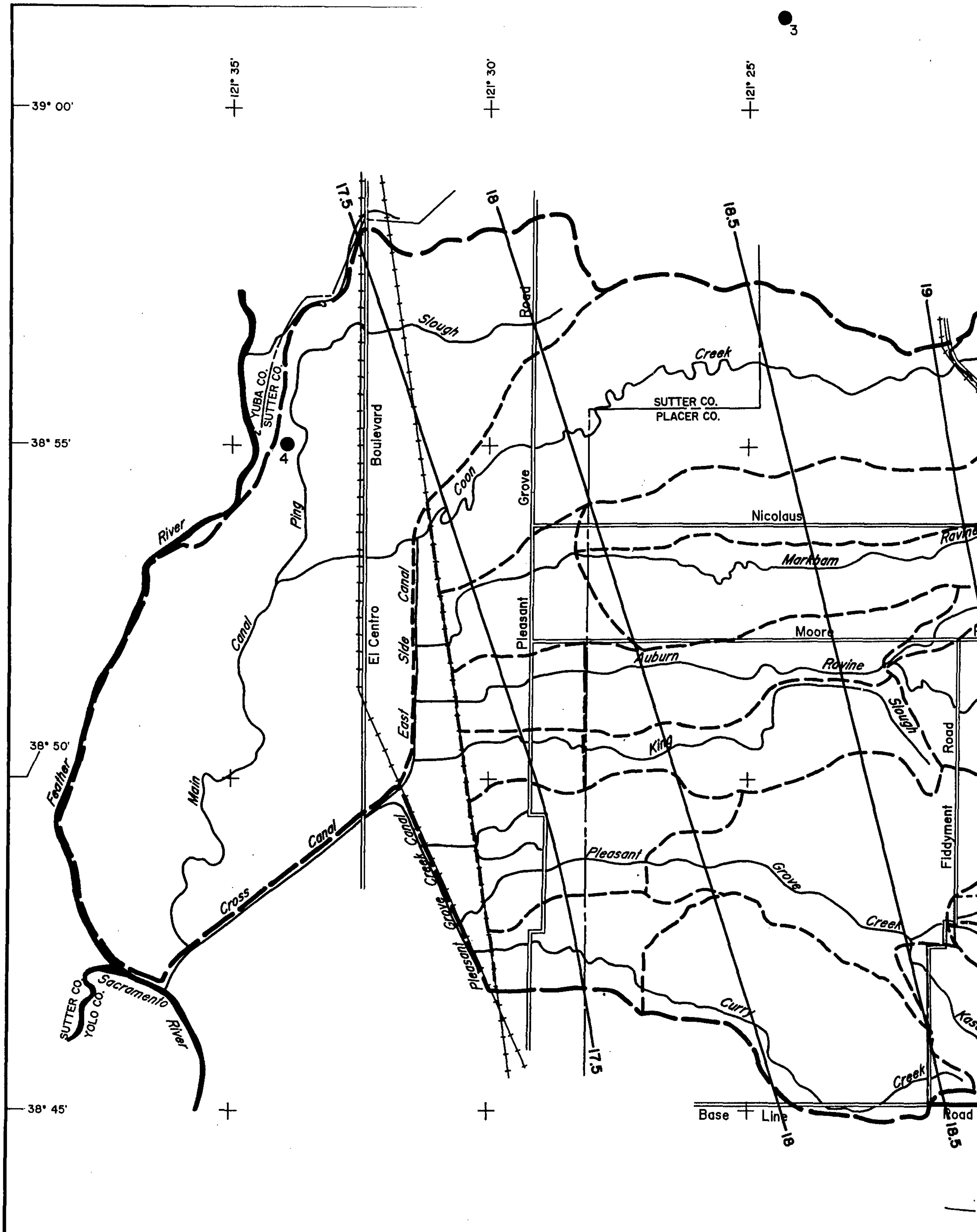
Prepared: J.H.
Drawn: C.A.P.

Date: JAN 1990

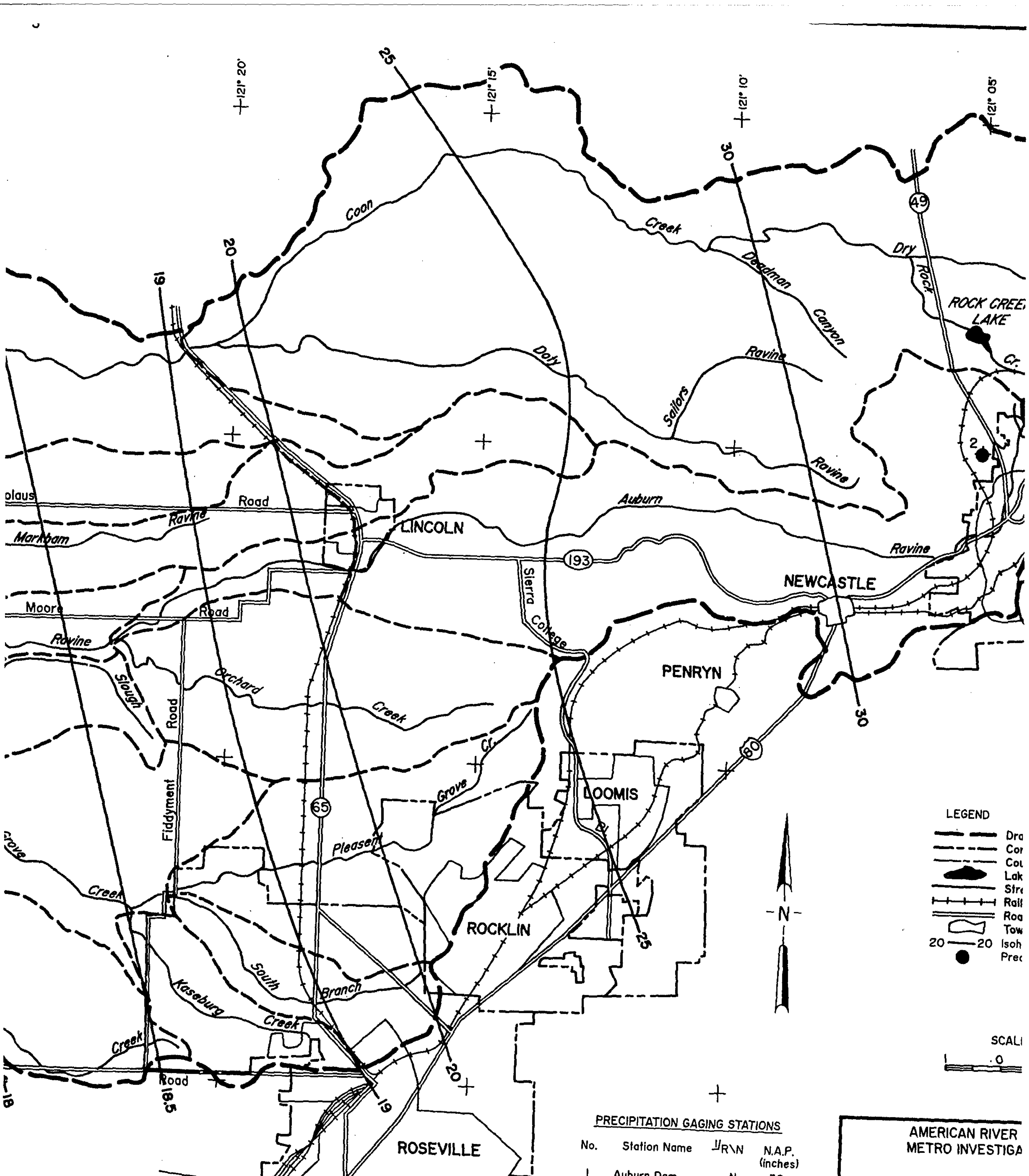
121° 10'

3

CHART 20



39° 00'
38° 55'
38° 50'
38° 45'
121° 35'
121° 30'
121° 25'
3
4
17.5
18
18.5
19
YUBA CO.
SUTTER CO.
PLACER CO.
YOLO CO.
Feather
River
Sacramento
River
Slough
Creek
Coon
Ping
Main
Canal
Cross
Canal
East
Side
Canal
El Centro
Boulevard
Pleasant
Grove
Road
Nicolaus
Ravine
Markham
Moore
Auburn
Ravine
Slough
King
Pleasant
Grove
Creek
Canal
Curry
Creek
Fiddyment
Road
Base
Line
Road



PRECIPITATION GAGING STATIONS

No.	Station Name	R\N [1]	N.A.P. (inches)
1	Auburn Dam	N	32
2	Auburn	N	33
3	Wheatland 2NE	R	19
4	Nicolaus 2	N	17

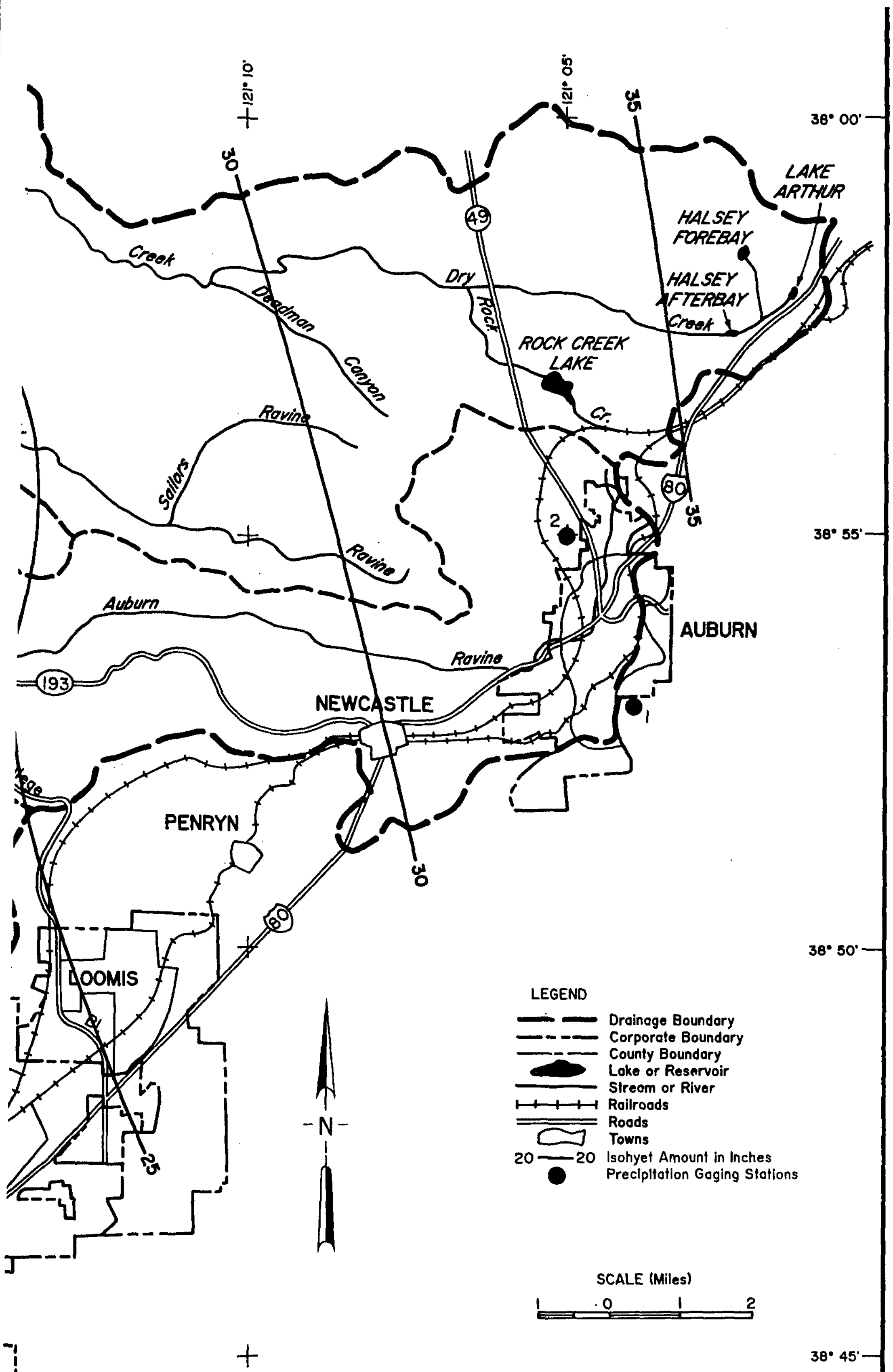
[1] Recorder\Non-Recorder

AMERICAN RIVER
METRO INVESTIGA

NATOMAS C
NORMAL
PRECIPITA

CORPS OF ENGINEERS S

Prepared: J.H.
Drawn: C.A.P.



PRECIPITATION GAGING STATIONS

No.	Station Name	1/ R\N	N.A.P. (inches)
1	Auburn Dam	N	32
2	Auburn	N	33
3	Wheatland 2NE	R	19
4	Nicolaus 2	N	17

1/ Recorder\Non-Recorder

AMERICAN RIVER AND SACRAMENTO METRO INVESTIGATIONS, CALIFORNIA

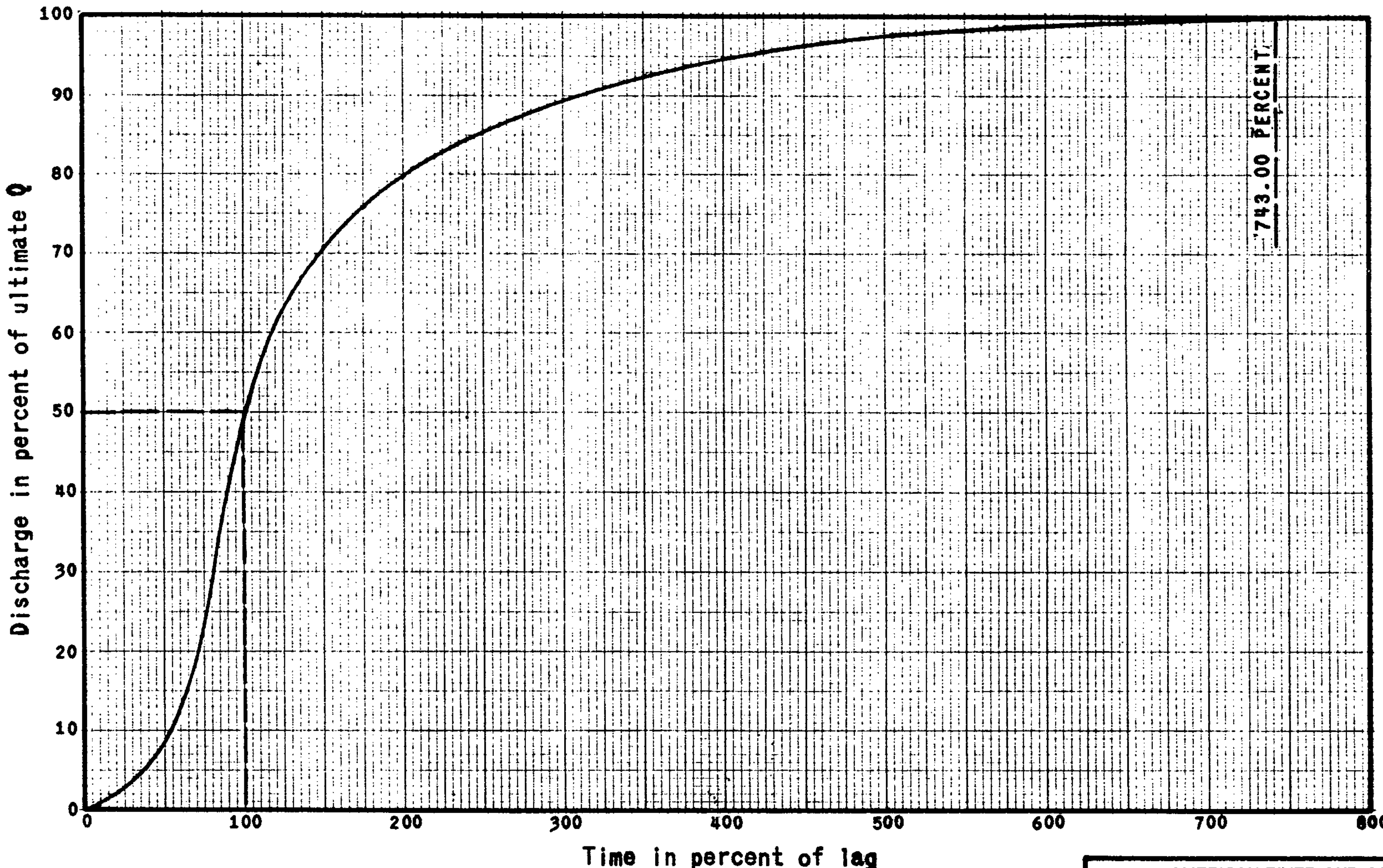
NATOMAS CROSS CANAL NORMAL ANNUAL PRECIPITATION MAP

CORPS OF ENGINEERS SACRAMENTO, CALIFORNIA

Prepared: J.H.
Drawn: C.A.P.

Date: JAN 1990

CHART 21

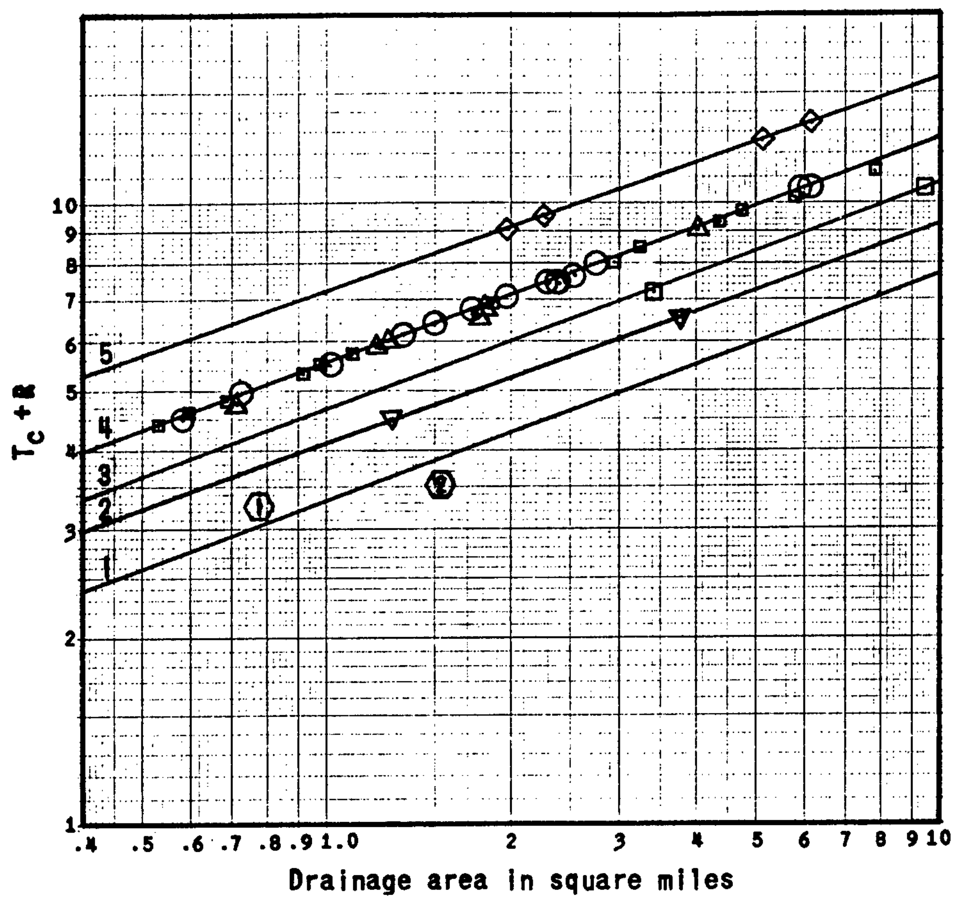


AMERICAN RIVER AND SACRAMENTO
METRO INVESTIGATIONS, CALIFORNIA

L.A.-VALLEY S-GRAPH

CORPS OF ENGINEERS, SACRAMENTO, CALIFORNIA

Prepared: P.W.
Drawn: C.A.P.
Date: JANUARY 1990



LEGEND:

- ◇ Laguna Creek between Eagles Nest and Bond Roads.
- ▫ Morrison Creek.
- ○ Laguna Creek below Bond Road.
- △ Elder Creek below Bradshaw Road.
- ▽ Elder Creek above Bradshaw Road.
- □ Laguna Creek above Eagles Nest Road.
- ⓵ Random Slough (11 Jan 73).
- ⓶ Coyle Creek (12 Jan 69).

NOTE:

Tc + R relationships are based on January 1982 flood reproduction. Areas represented by lines 1-5 are described in Chapter IV, section 2.

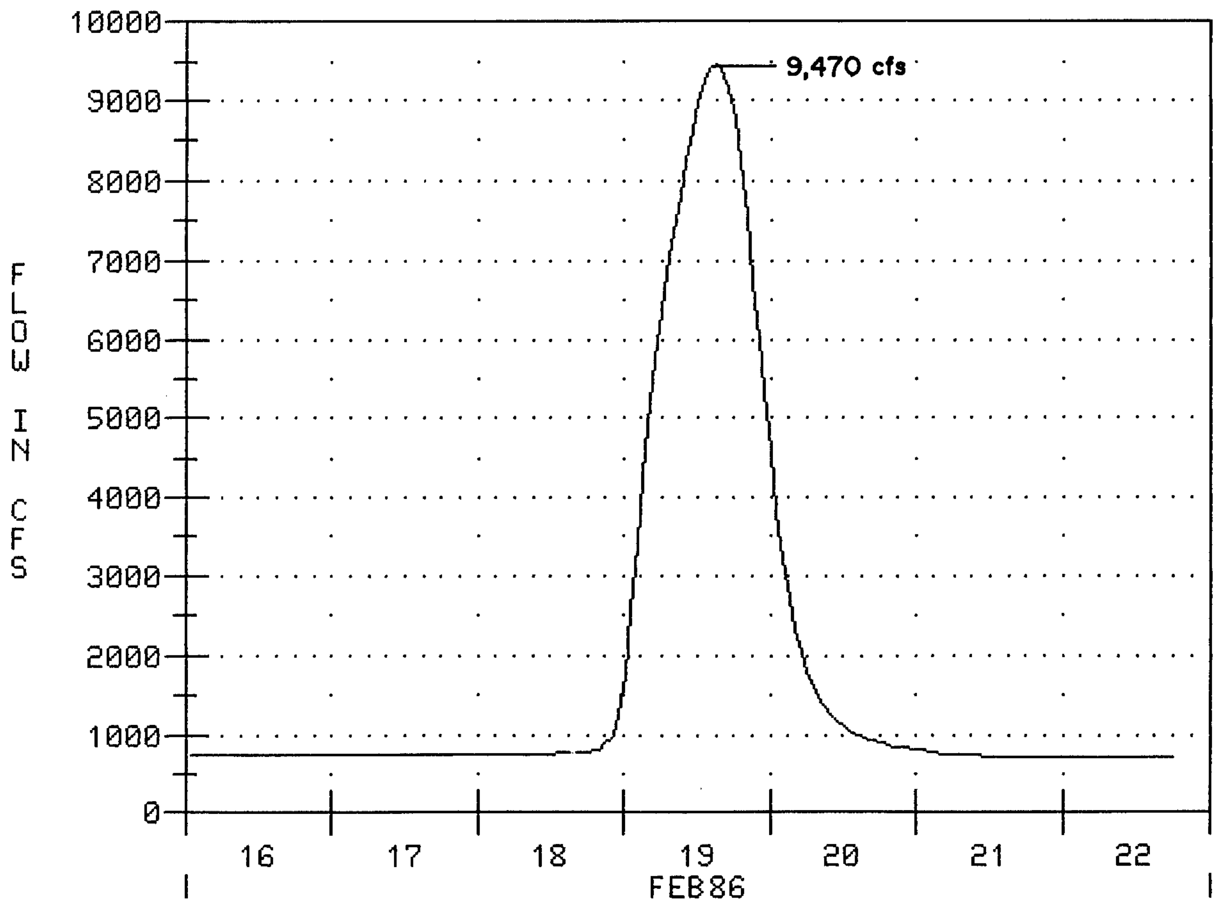
AMERICAN RIVER AND SACRAMENTO METRO INVESTIGATIONS, CALIFORNIA

T_c + R RELATIONSHIPS

CORPS OF ENGINEERS, SACRAMENTO, CALIFORNIA

Prepared: J.H.
Drawn: C.A.P.

Date: JANUARY 1990



AMERICAN RIVER AND SACRAMENTO
METRO INVESTIGATIONS, CALIFORNIA

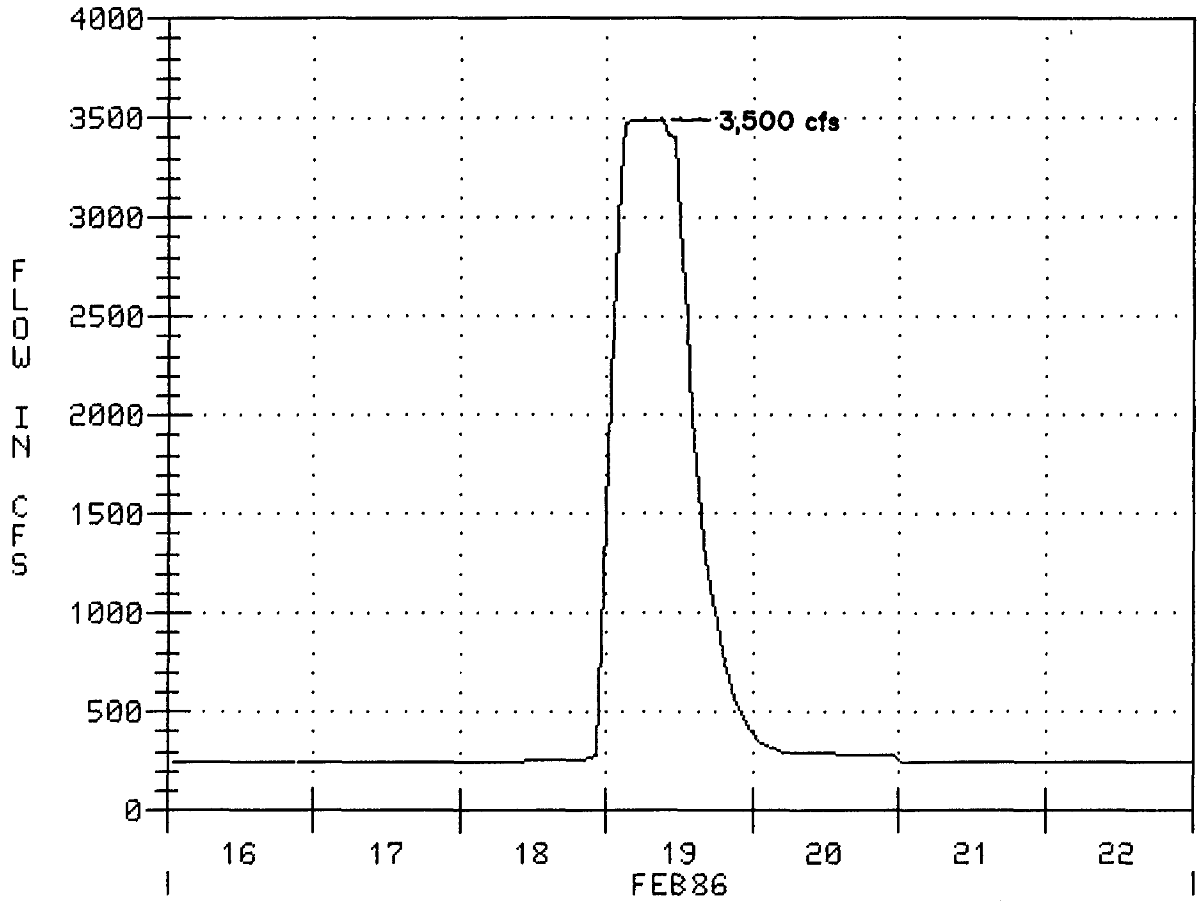
1986 COMPUTED HYDROGRAPH

DRY CREEK @ MOUTH

CORPS OF ENGINEERS. SACRAMENTO. CALIFORNIA

Prepared: J.H.
Drawn: C.A.P.
Date: JANUARY 1990

SHEET 1 OF 3 CHART 24



AMERICAN RIVER AND SACRAMENTO
METRO INVESTIGATIONS, CALIFORNIA

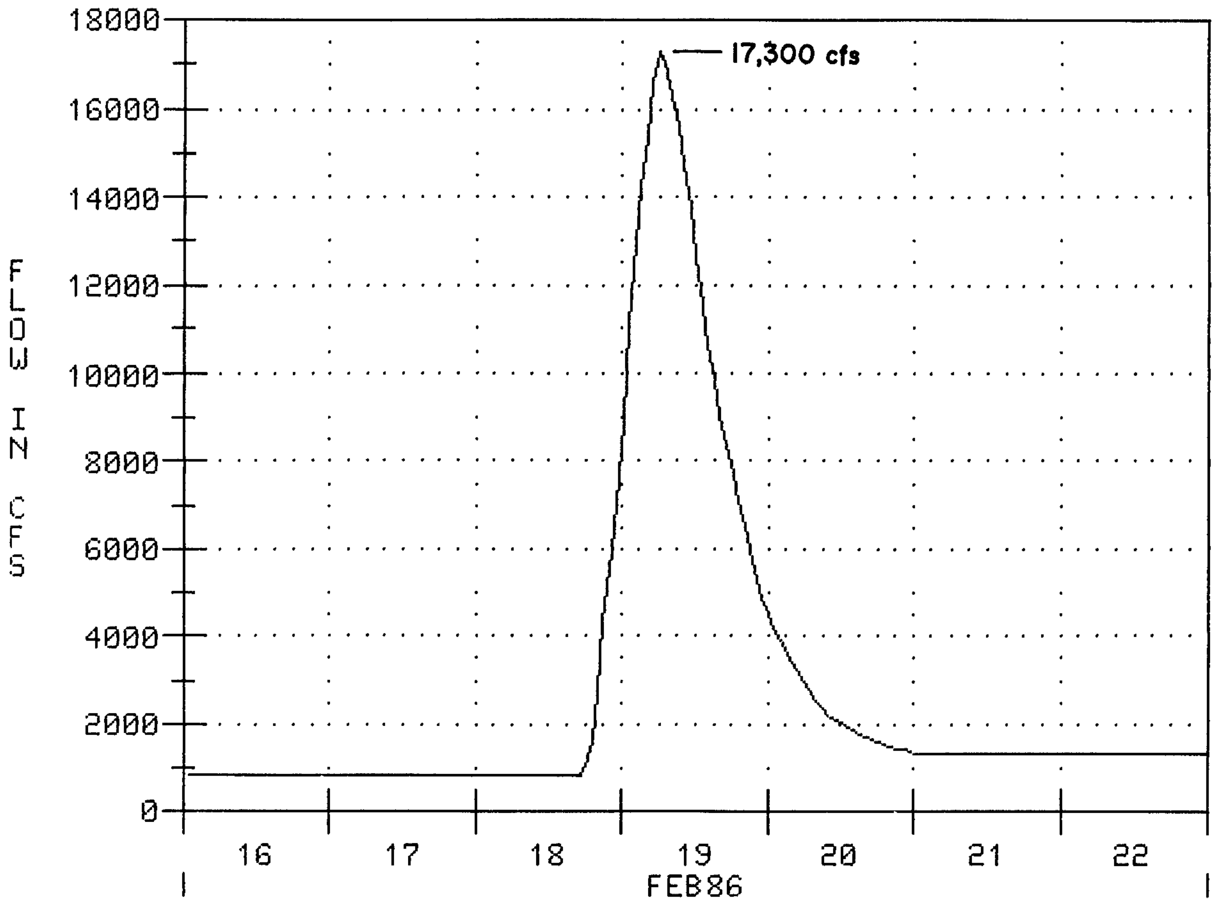
1986 COMPUTED HYDROGRAPH

ARCADE CREEK @ MOUTH

CORPS OF ENGINEERS. SACRAMENTO. CALIFORNIA

Prepared: J.H.
Drawn: C.A.P.
Date: JANUARY 1990

SHEET 2 OF 3 CHART 24



AMERICAN RIVER AND SACRAMENTO
METRO INVESTIGATIONS, CALIFORNIA

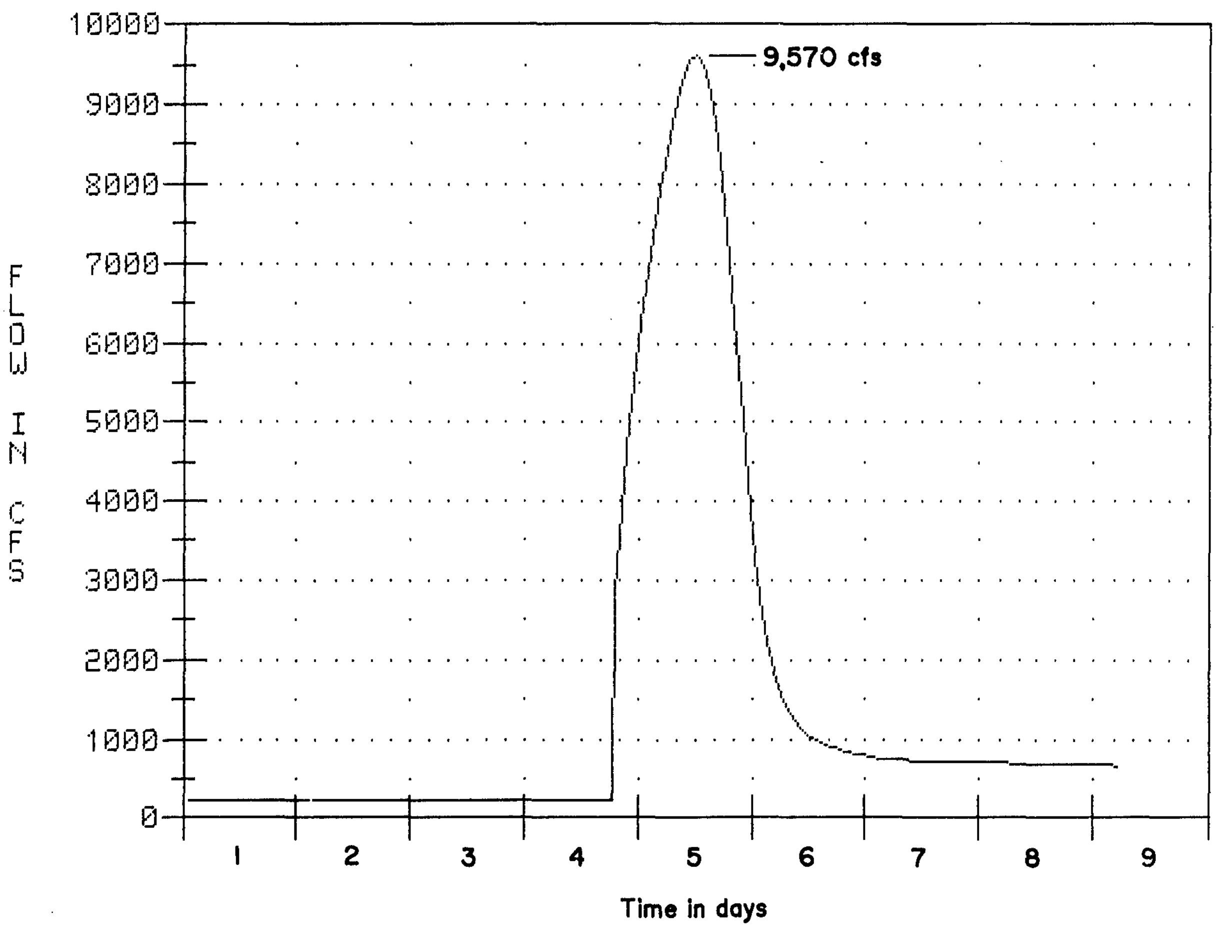
1986 COMPUTED HYDROGRAPH

INFLOW TO NATOMAS CROSS CANAL

CORPS OF ENGINEERS, SACRAMENTO, CALIFORNIA

Prepared: J.H.
Drawn: C.A.P.
Date: JANUARY 1990

SHEET 3 OF 3 CHART 24



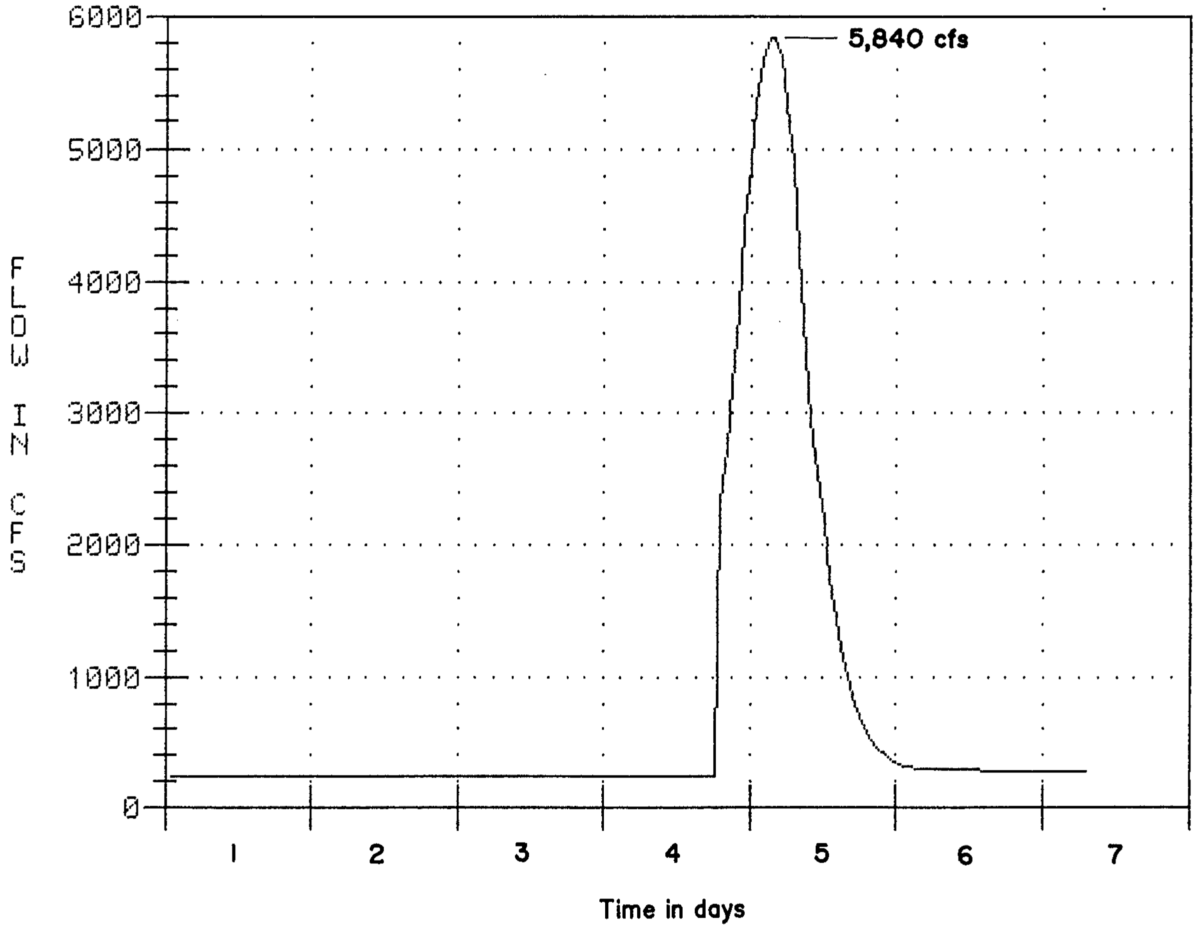
AMERICAN RIVER AND SACRAMENTO
METRO INVESTIGATIONS, CALIFORNIA

100-YR. COMPUTED HYDROGRAPH

DRY CREEK @ MOUTH

CORPS OF ENGINEERS, SACRAMENTO, CALIFORNIA

Prepared: J.H.
Drawn: C.A.P.
Date: JANUARY 1990



AMERICAN RIVER AND SACRAMENTO
METRO INVESTIGATIONS, CALIFORNIA

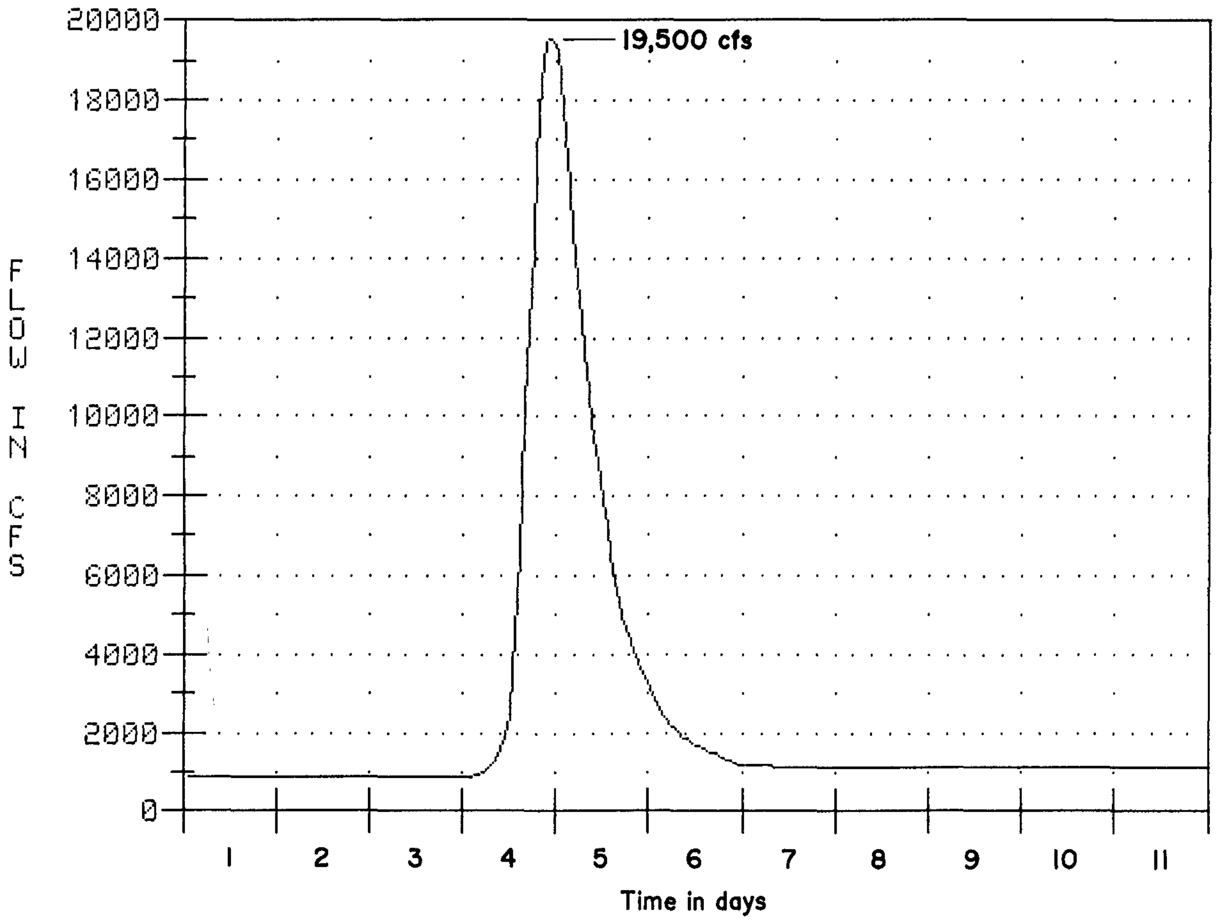
100-YR. COMPUTED HYDROGRAPH

ARCADE CREEK @ MOUTH

CORPS OF ENGINEERS, SACRAMENTO, CALIFORNIA

Prepared: J.H.
Drawn: C.A.P.
Date: JANUARY 1990

SHEET 2 OF 3 CHART 25



AMERICAN RIVER AND SACRAMENTO
METRO INVESTIGATIONS, CALIFORNIA

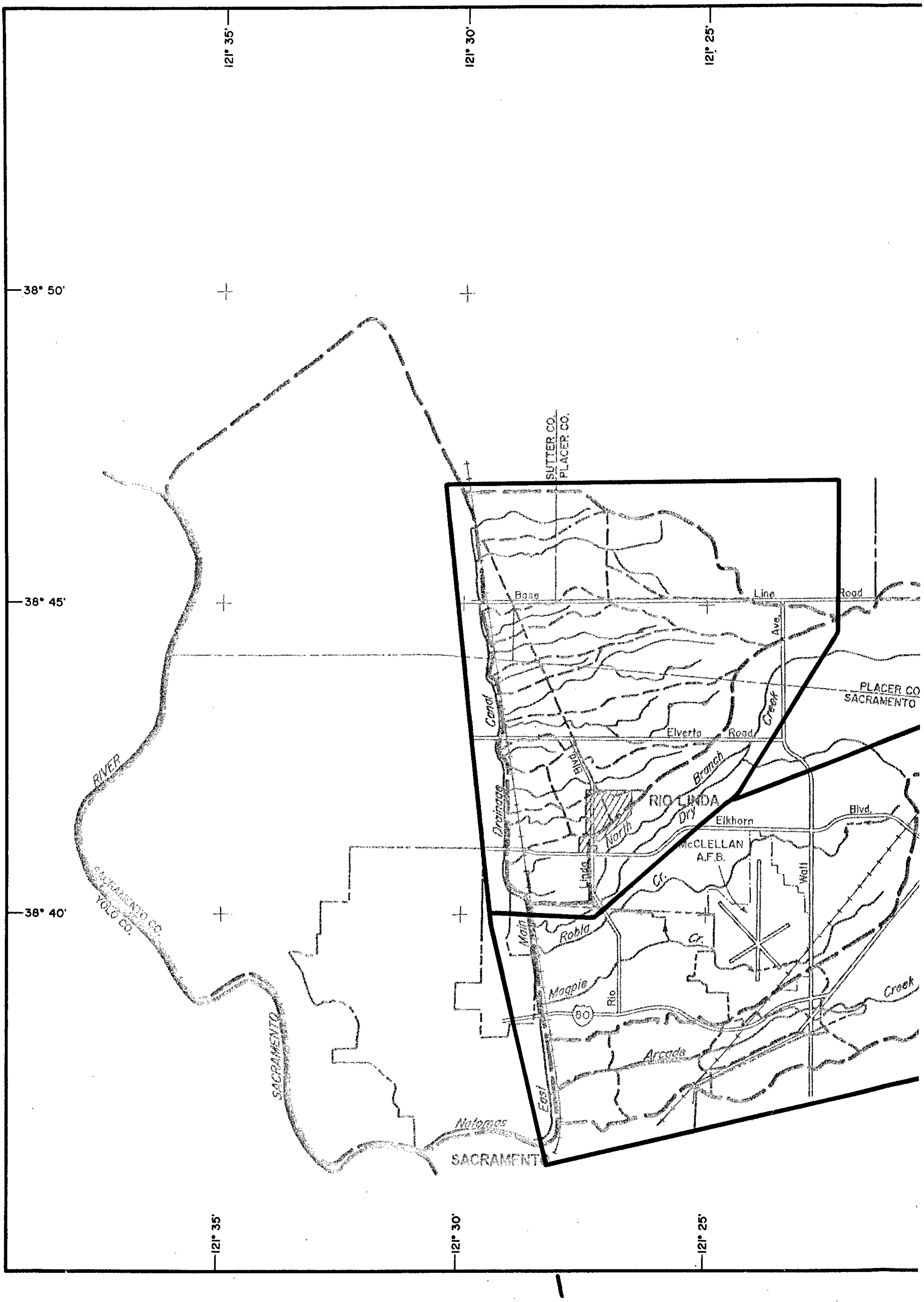
100-YR. COMPUTED HYDROGRAPH

INFLOW TO NATOMAS CROSS CANAL

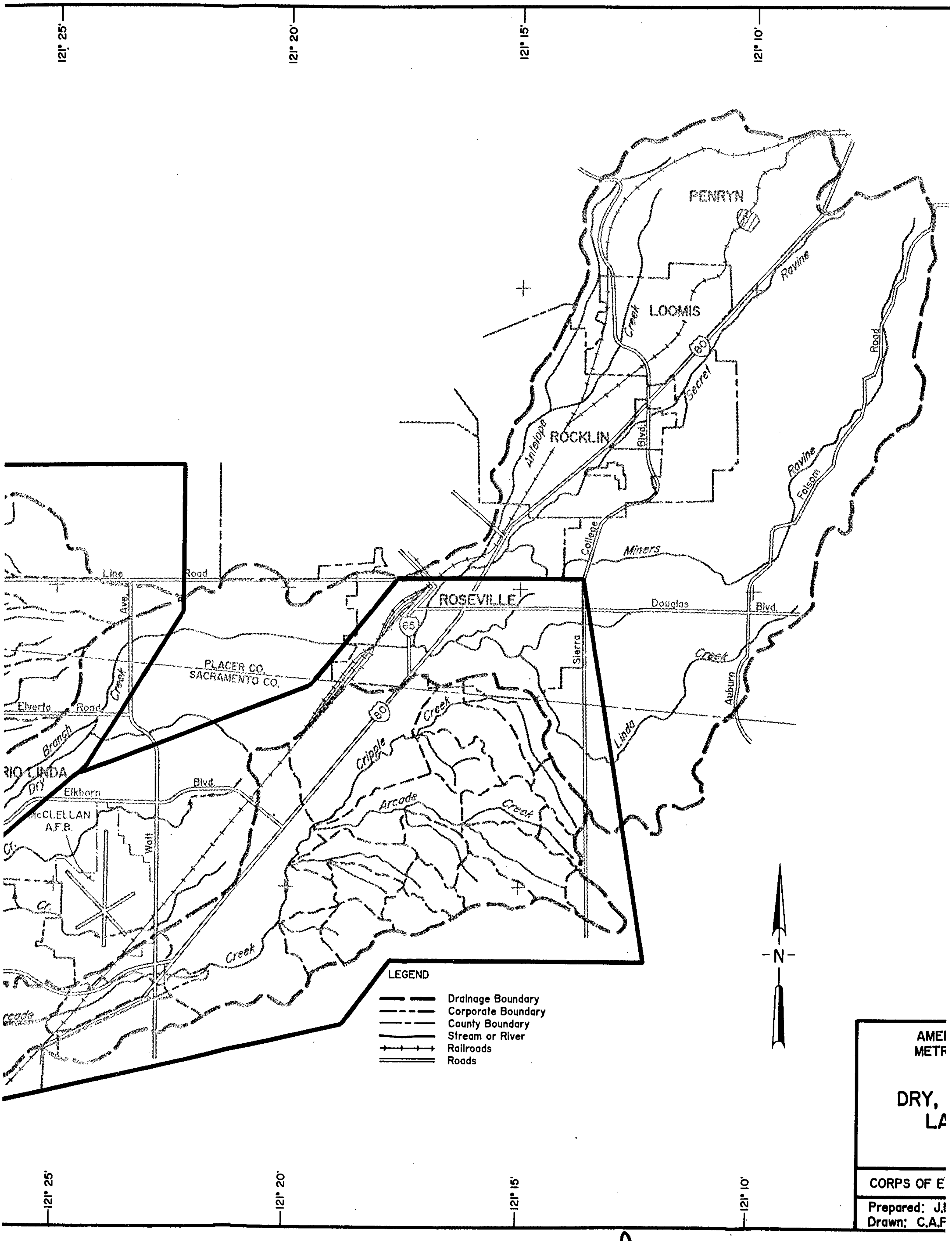
CORPS OF ENGINEERS. SACRAMENTO. CALIFORNIA

Prepared: J.H.
Drawn: C.A.P.
Date: JANUARY 1990

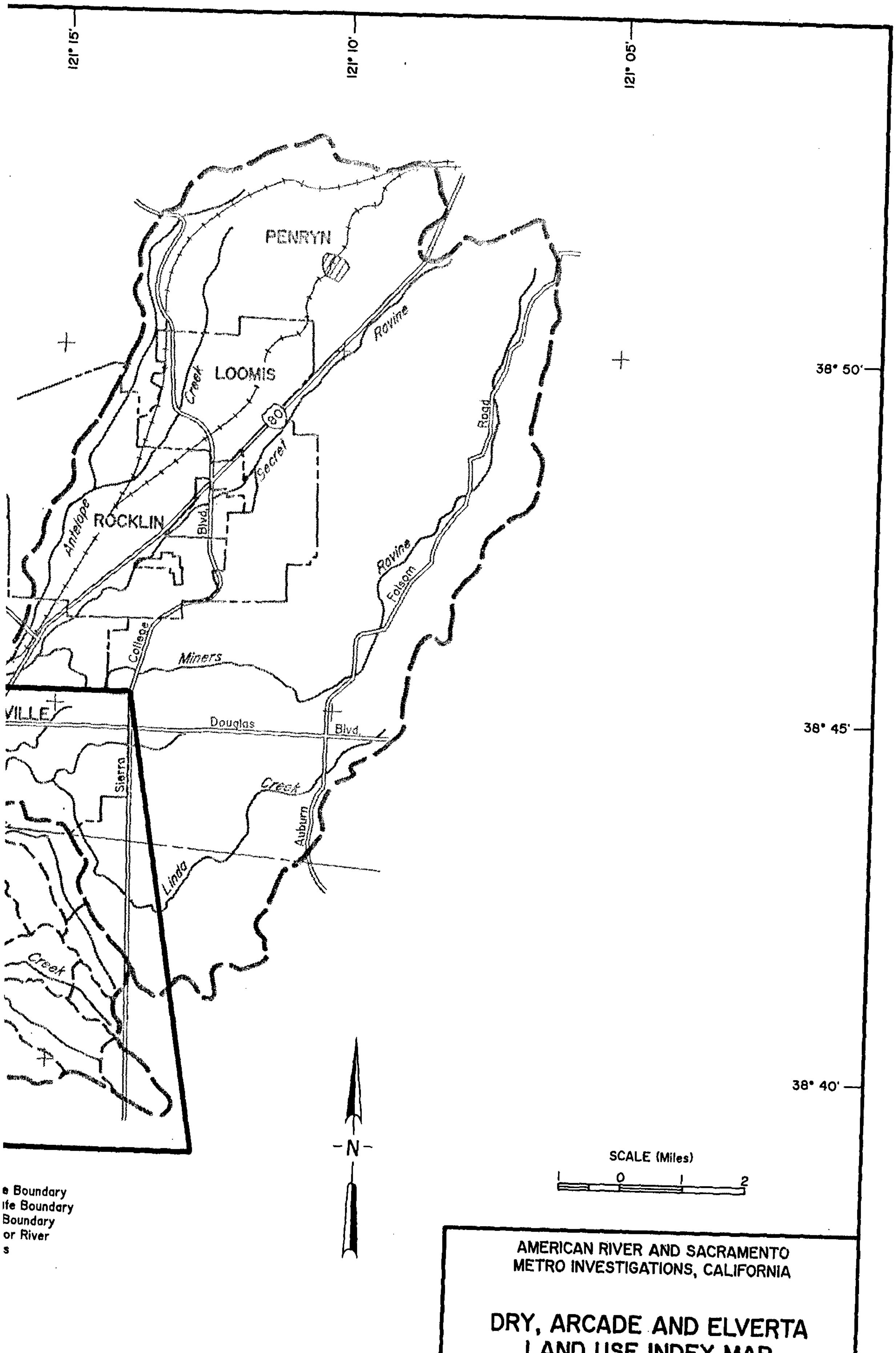
SHEET 3 OF 3 CHART 25



121° 35'
121° 30'
121° 25'
38° 50'
38° 45'
38° 40'
SUTTER CO.
PLACER CO.
Base
Line
Road
Ave.
PLACER CO
SACRAMENTO
Canal
Drainage
Elverta
Road
Creek
Blvd.
Branch
RIO LINDA
Dry
North
Elkhorn
Blvd.
McCLELLAN
A.F.B.
Linda
Cr.
Walt
RIVER
SACRAMENTO CO.
YOLO CO.
Main
Robla
Cr.
Magpie
Rio
60
Creek
Arcade
SACRAMENTO
East
Natomas
SACRAMENTO



121° 25'
121° 20'
121° 15'
121° 10'
PENRYN
LOOMIS
ROCKLIN
ROSEVILLE
RIO LINDA
McCLELLAN A.F.B.
PLACER CO.
SACRAMENTO CO.
Antelope Creek
Secret Ravine
Miners Ravine
Linda Creek
Cripple Creek
Arcade Creek
Dry Creek
Branch
Line Road
Elverta Road
Elkhorn Blvd.
Douglas Blvd.
Auburn Folsom Road
Sierra
College
Watt Ave.
Blvd.
80
65
LEGEND
Drainage Boundary
Corporate Boundary
County Boundary
Stream or River
Railroads
Roads
N
AMEI
METR
DRY,
LA
CORPS OF E
Prepared: J.I
Drawn: C.A.F



AMERICAN RIVER AND SACRAMENTO
METRO INVESTIGATIONS, CALIFORNIA

DRY, ARCADE AND ELVERTA LAND USE INDEX MAP

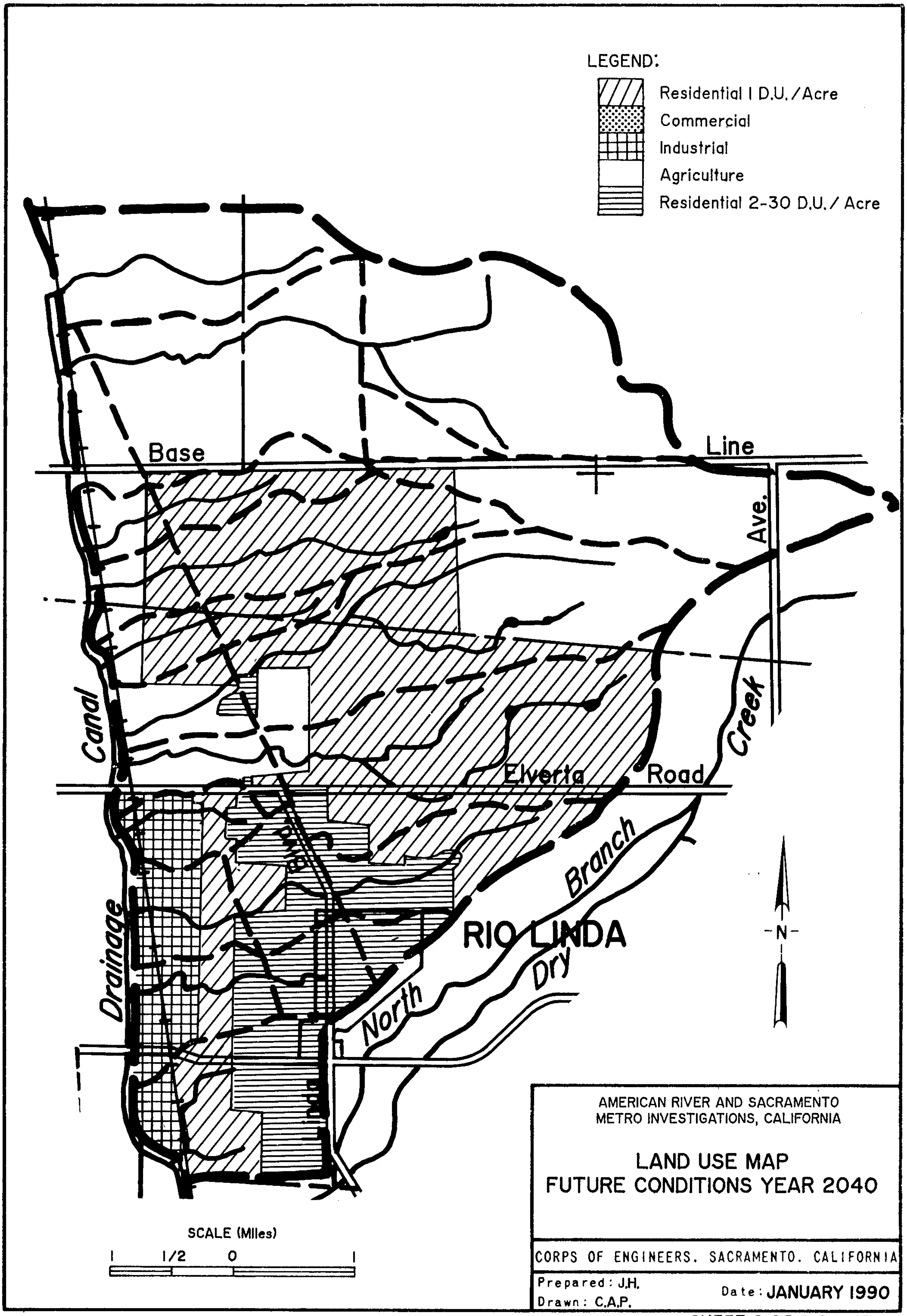
CORPS OF ENGINEERS SACRAMENTO, CALIFORNIA

Prepared: J.H.
Drawn: C.A.P.

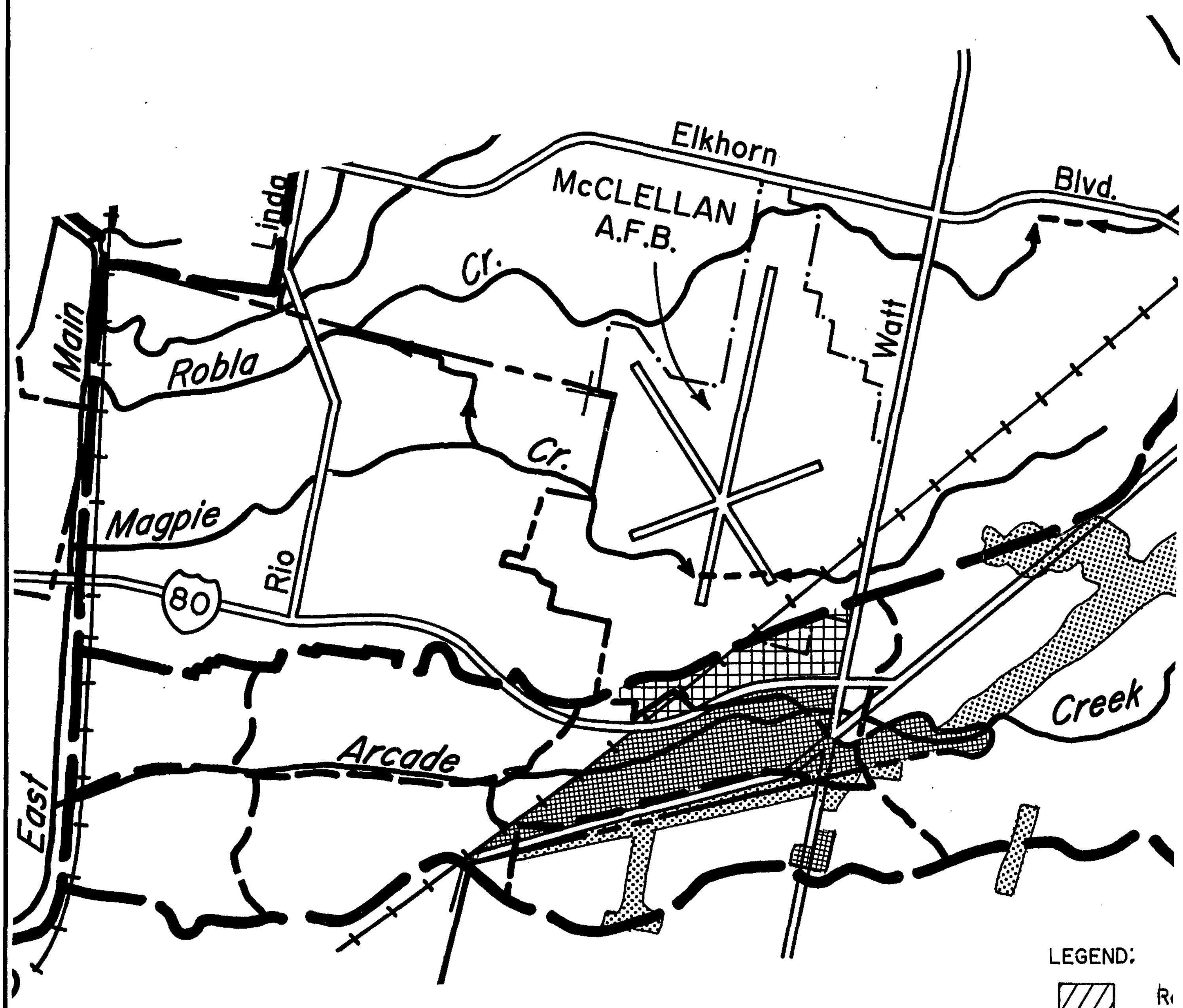
Date: JANUARY 1990

3

SHEET 1 OF 3 CHART 26

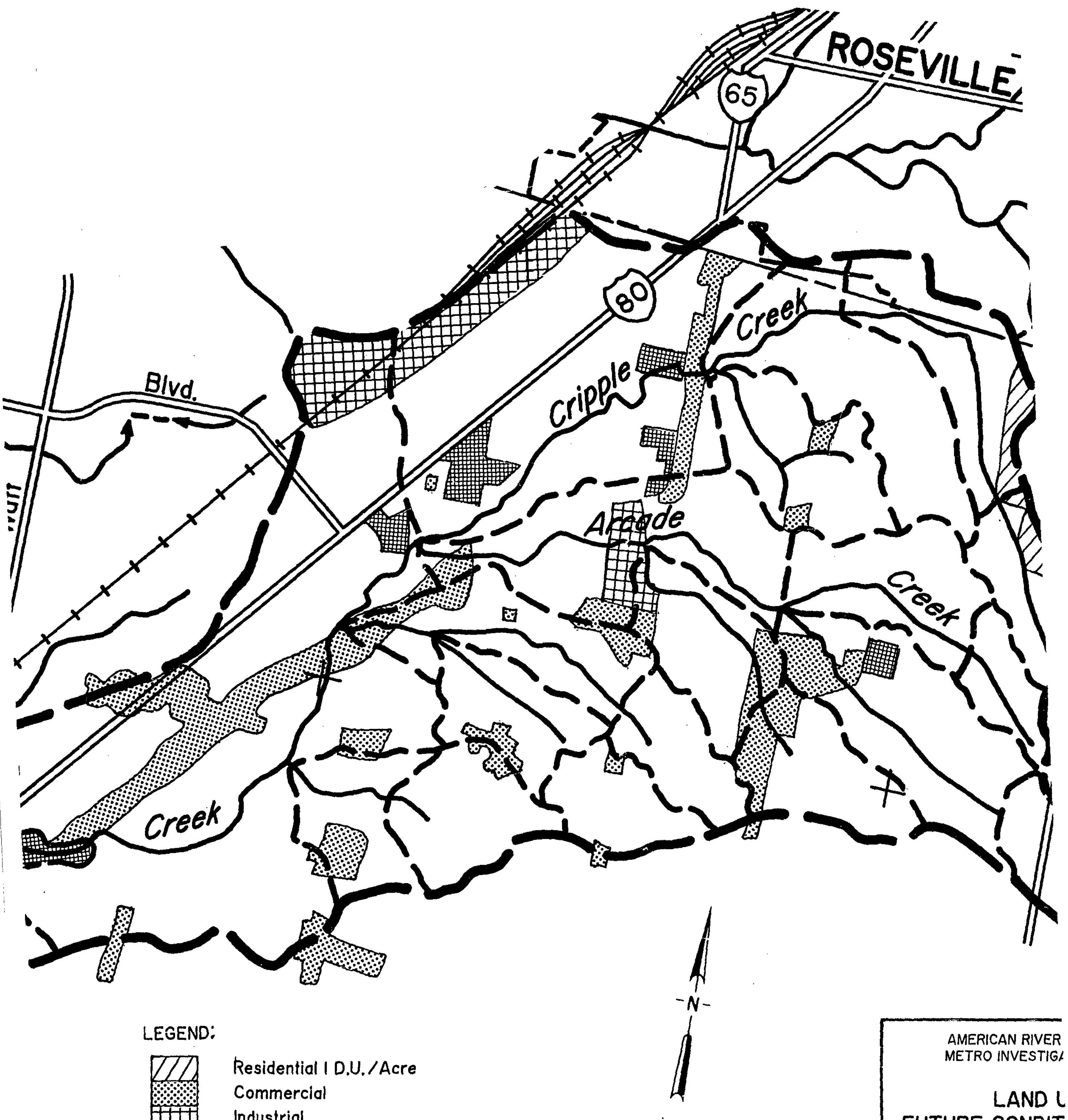


SHEET 2 OF 3 CHART 26



Elkhorn
Blvd.
McCLELLAN
A.F.B.
Linda
Cr.
Robla
Main
Watt
Cr.
Magpie
Rio
80
Creek
Arcade
East

LEGEND:



LEGEND:

- Residential 1 D.U./Acre
- Commercial
- Industrial
- Recreation - Agriculture
- Residential 2-30 D.U./Acre

SCALE (Miles)

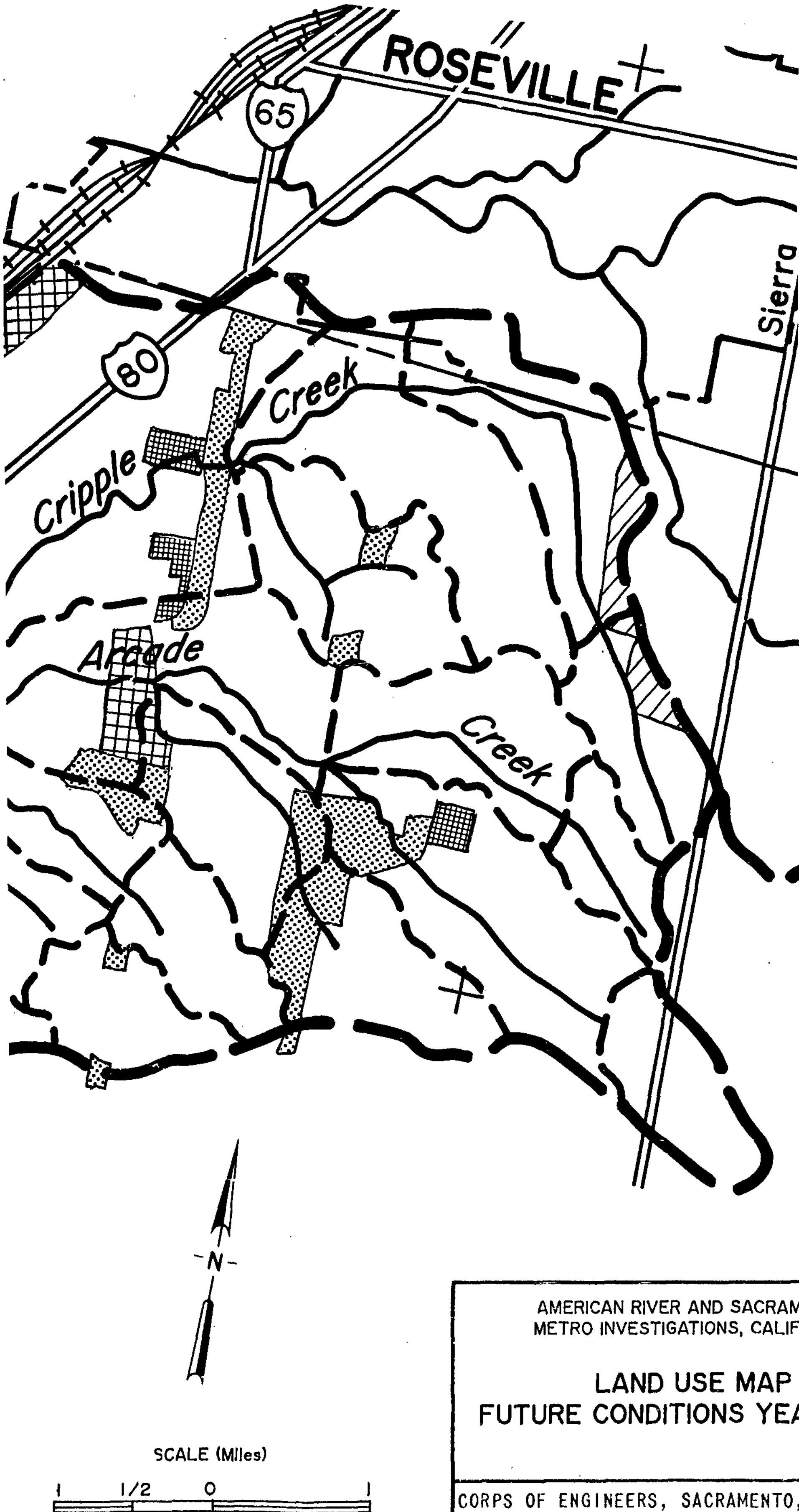
1 1/2 0 1

AMERICAN RIVER
METRO INVESTIG

LAND U
FUTURE CONDIT

CORPS OF ENGINEERS, S

Prepared: J.H.
Drawn: C.A.P.



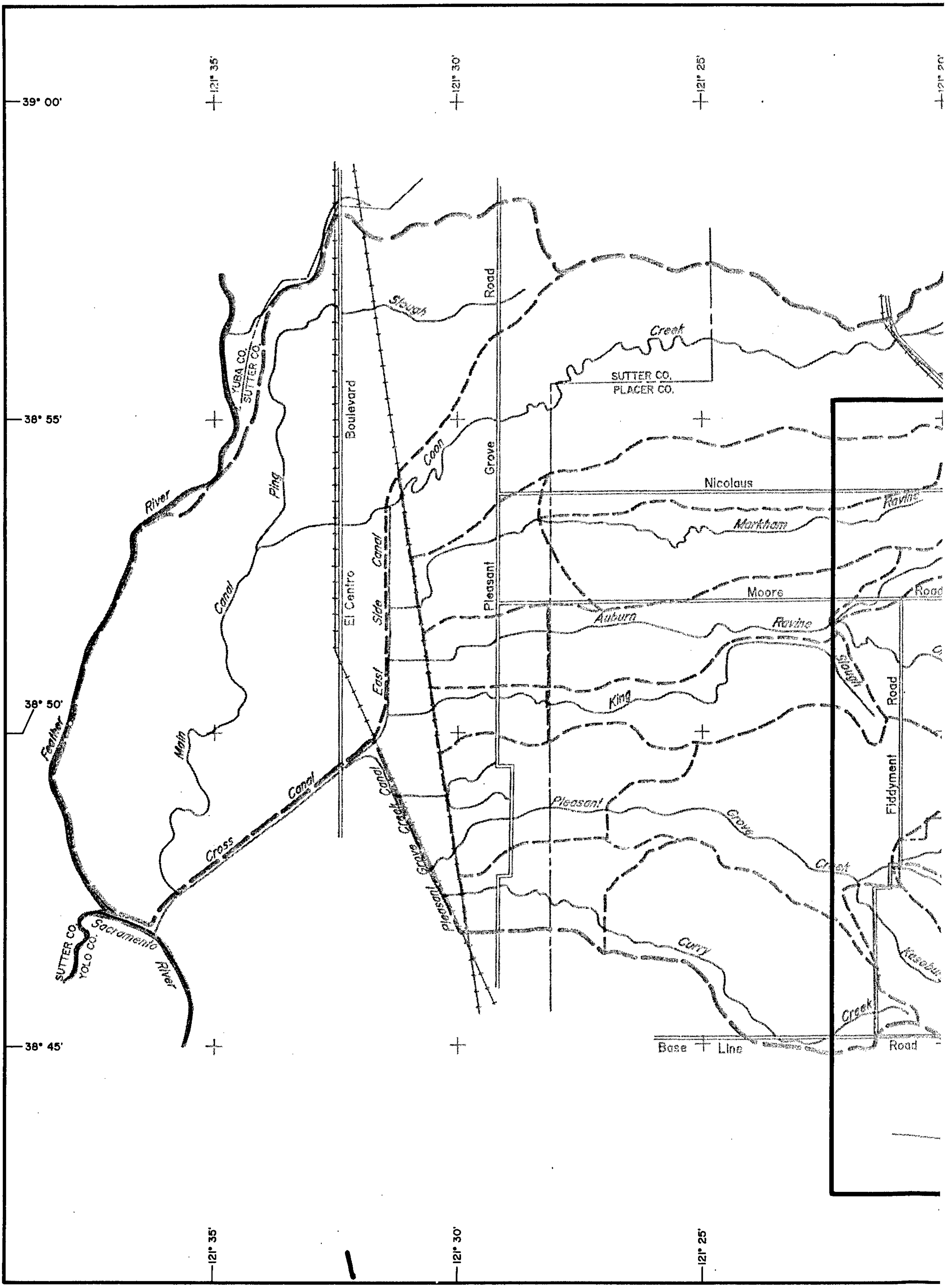
AMERICAN RIVER AND SACRAMENTO
METRO INVESTIGATIONS, CALIFORNIA

LAND USE MAP
FUTURE CONDITIONS YEAR 2040

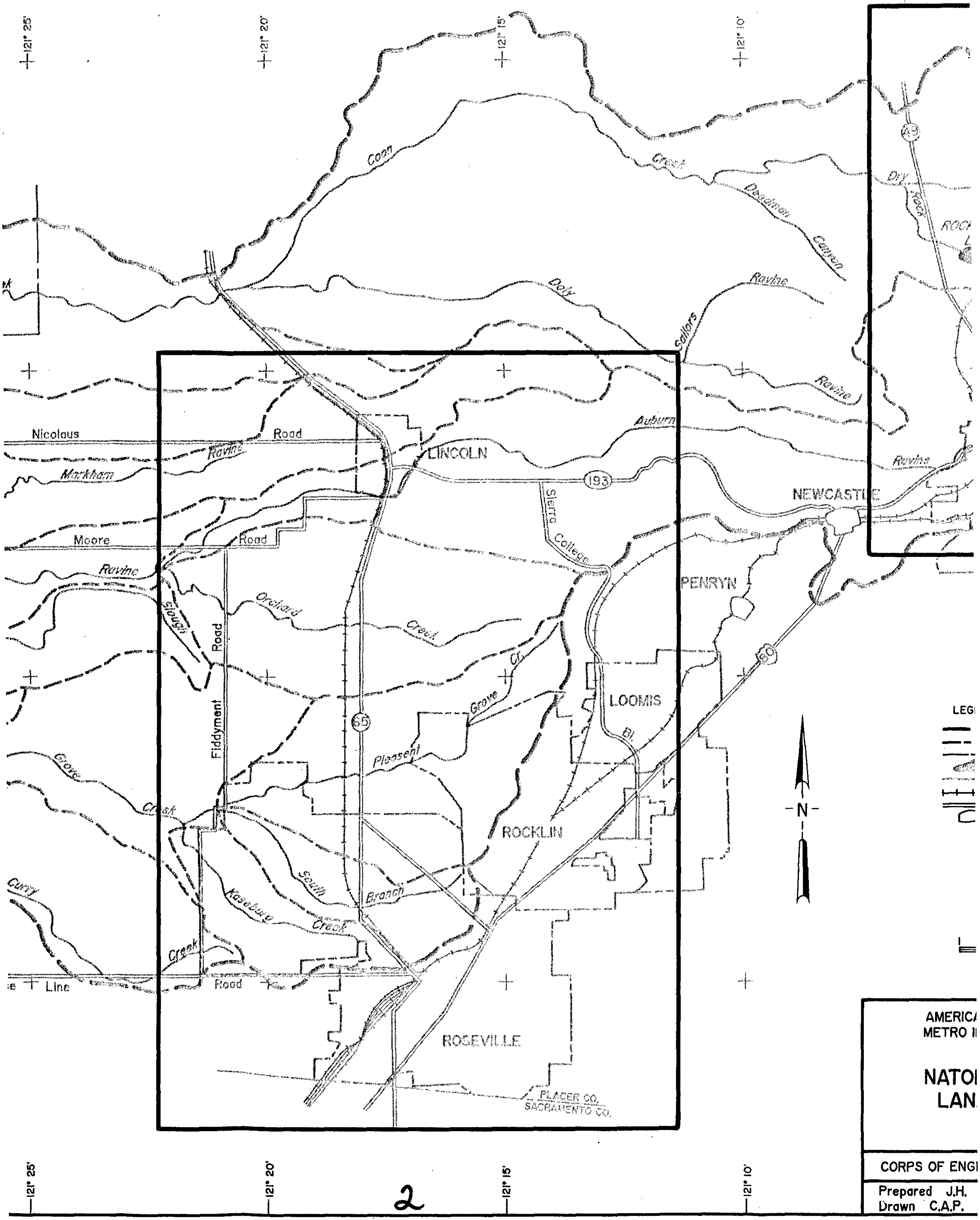
CORPS OF ENGINEERS, SACRAMENTO, CALIFORNIA

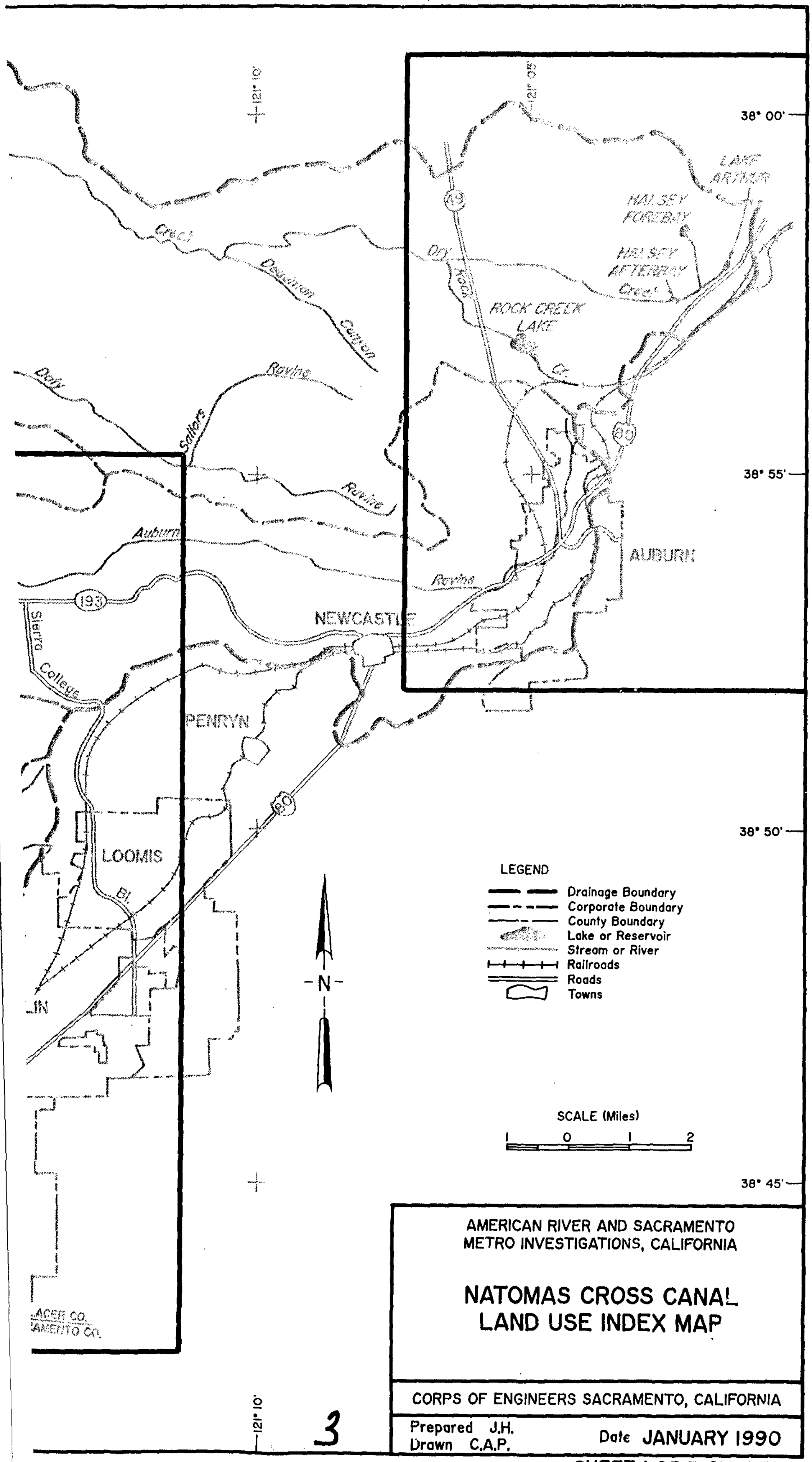
Prepared: J.H.
Drawn: C.A.P.
Date:

3



39° 00'
38° 55'
38° 50'
38° 45'
121° 35'
121° 30'
121° 25'
YUBA CO.
SUTTER CO.
SUTTER CO.
PLACER CO.
SUTTER CO.
YOLO CO.
Feather
River
Sacramento
River
Slough
Creek
Coon
Ping
Main
Canal
Cross
Canal
East
Side
Canal
El Centro
Boulevard
Pleasant
Grove
Road
Nicolaus
Markham
Ravine
Moore
Road
Auburn
Ravine
King
Pleasant
Grove
Creek
Pleasant
Grove
Creek
Canal
Curry
Creek
Fiddyment
Road
Base
Line
Road


121° 25'
121° 20'
121° 15'
121° 10'
Coon
Creek
Deadman
Canyon
Doty
Ravine
Sailors
Ravine
Dry
Rock
Nicolaus
Road
Ravine
Markham
LINCOLN
Auburn
193
Ravine
NEWCASTLE
Moore
Road
Ravine
Sierra
College
PENRYN
Orchard
Creek
Slough
Road
Fiddyment
Grove
Cr.
LOOMIS
Bl.
80
65
Pleasant
Grove
Creek
ROCKLIN
South
Branch
Kaseburg
Creek
Curry
Creek
Line
Road
ROSEVILLE
PLACER CO.
SACRAMENTO CO.
N
LEG
AMERICA
METRO I
NATO
LAN
CORPS OF ENGI
Prepared J.H.
Drawn C.A.P.



AMERICAN RIVER AND SACRAMENTO
METRO INVESTIGATIONS, CALIFORNIA

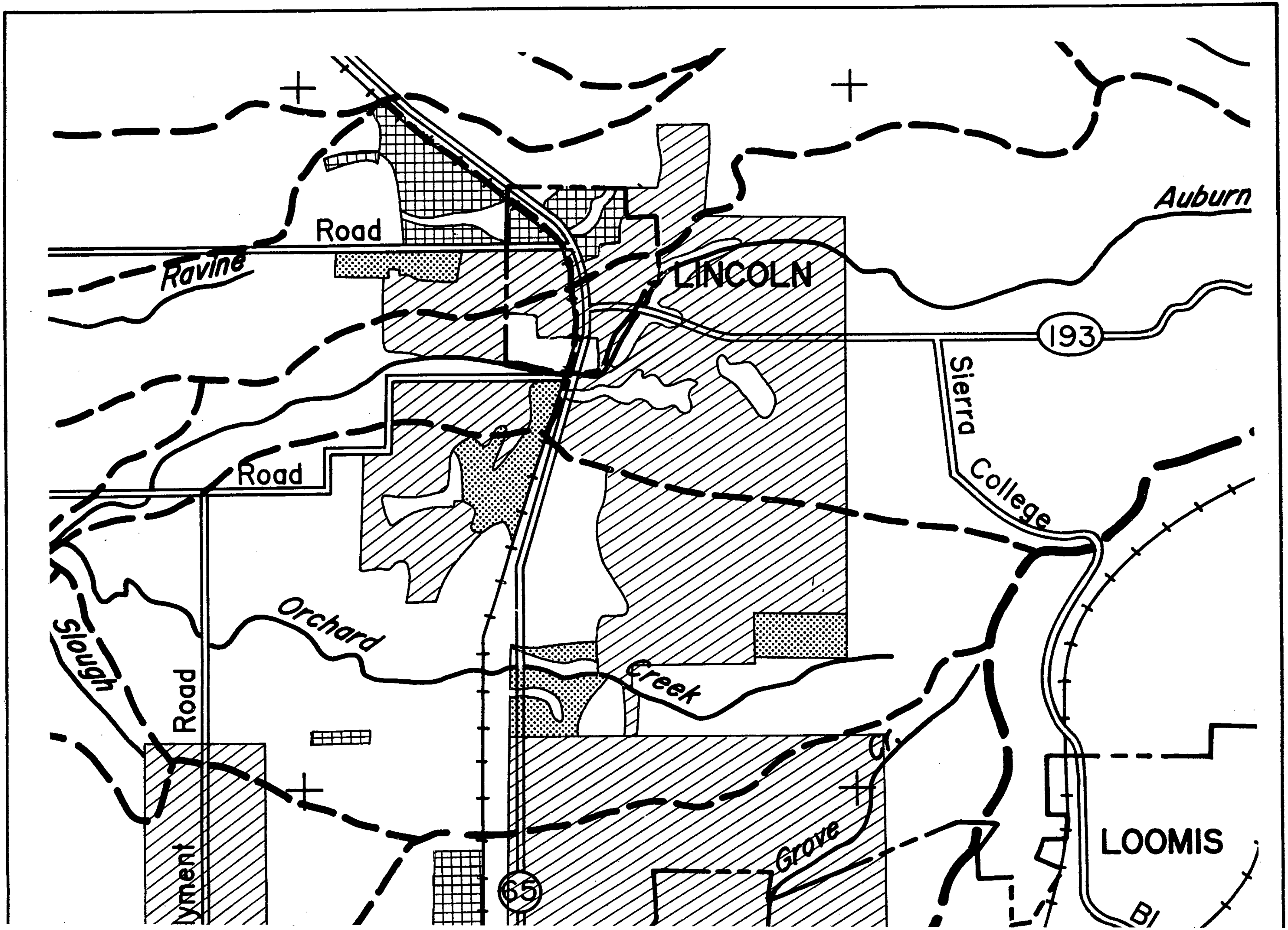
NATOMAS CROSS CANAL
LAND USE INDEX MAP

CORPS OF ENGINEERS SACRAMENTO, CALIFORNIA

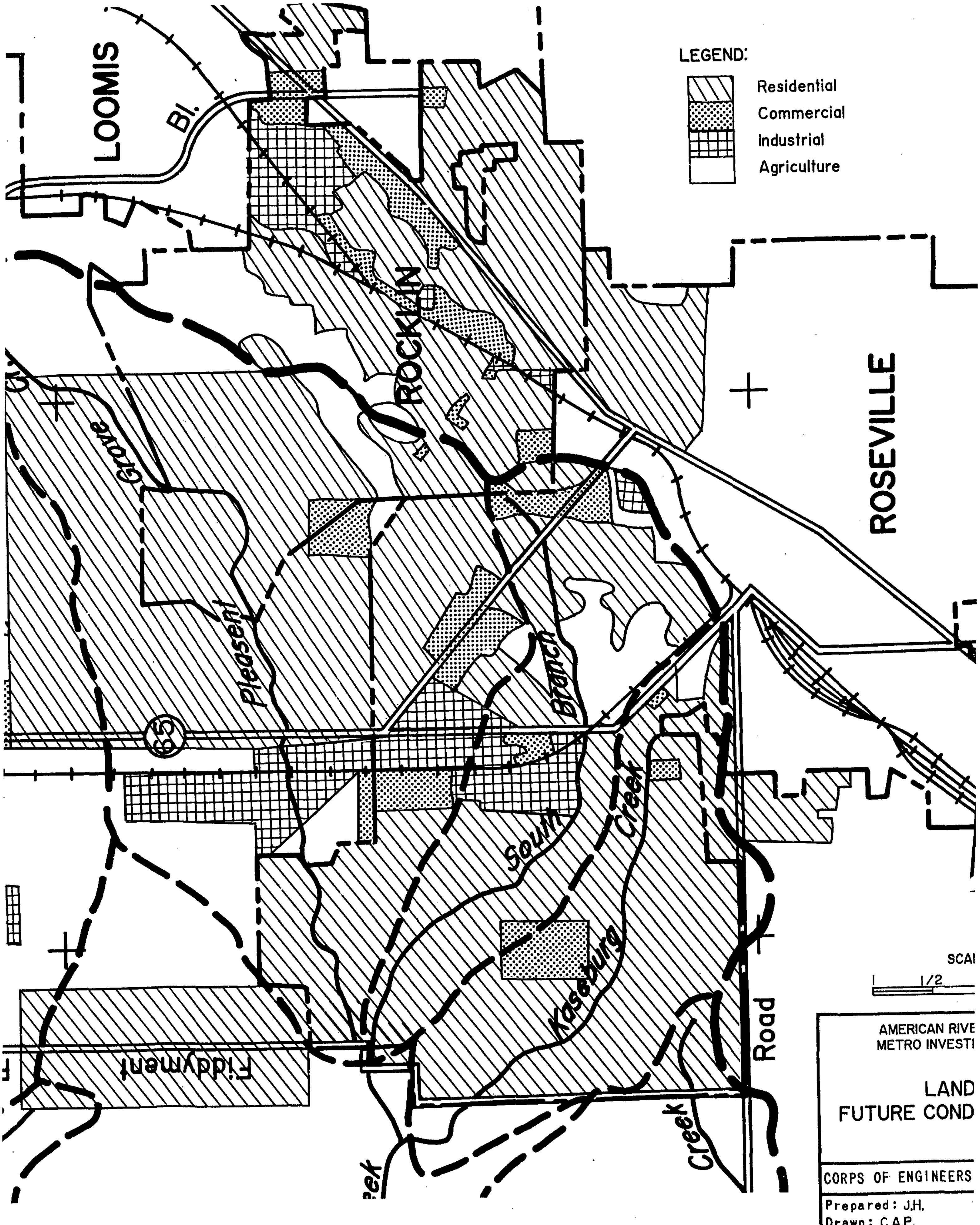
Prepared J.H.
Drawn C.A.P.

Date JANUARY 1990

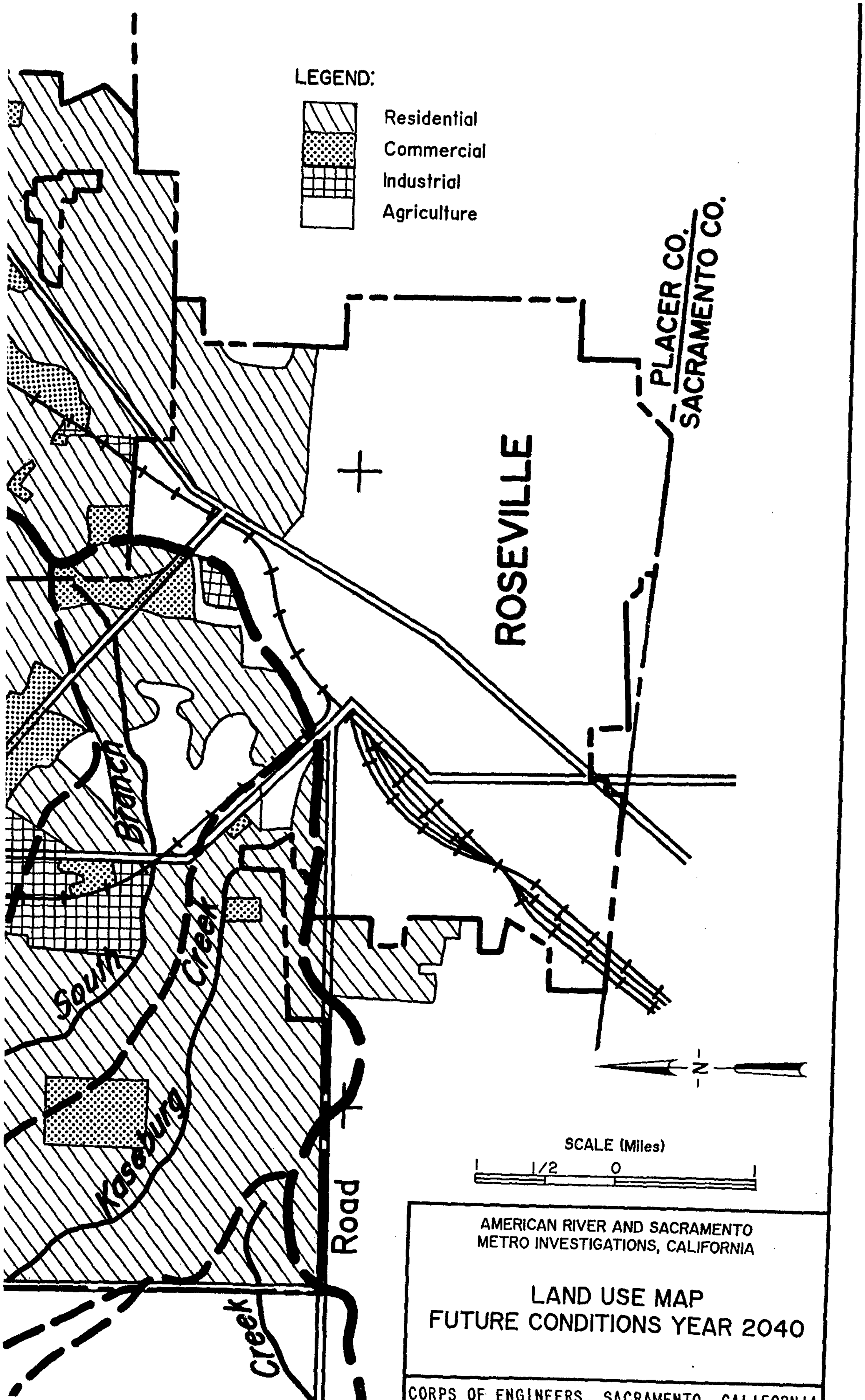
SHEET 1 OF 3 CHART 27



LINCOLN
LOOMIS
Auburn
Ravine
Road
193
Sierra College
Road
Orchard
Creek
Slough
Road
Grove
65



LEGEND:
Residential
Commercial
Industrial
Agriculture
LOOMIS
Bl.
ROCKLIN
ROSEVILLE
Grove
Pleasent
Branch
South
Creek
Kaseburg
Creek
Creek
Road
Fiddyment
65
SCAI
1/2
AMERICAN RIVE
METRO INVESTI
LAND
FUTURE COND
CORPS OF ENGINEERS
Prepared: J.H.
Drawn: C.A.P.



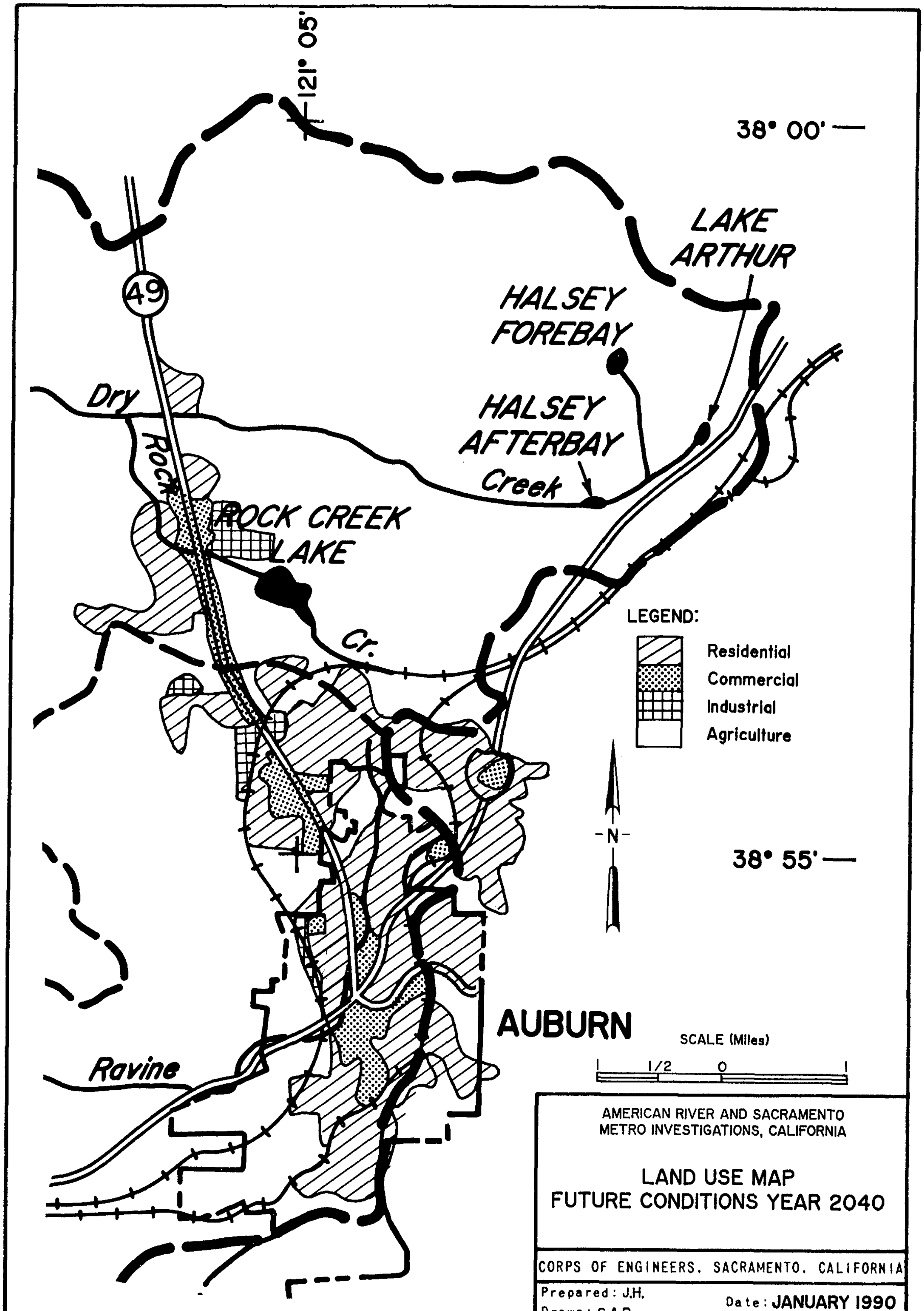
AMERICAN RIVER AND SACRAMENTO METRO INVESTIGATIONS, CALIFORNIA

LAND USE MAP
FUTURE CONDITIONS YEAR 2040

CORPS OF ENGINEERS, SACRAMENTO, CALIFORNIA

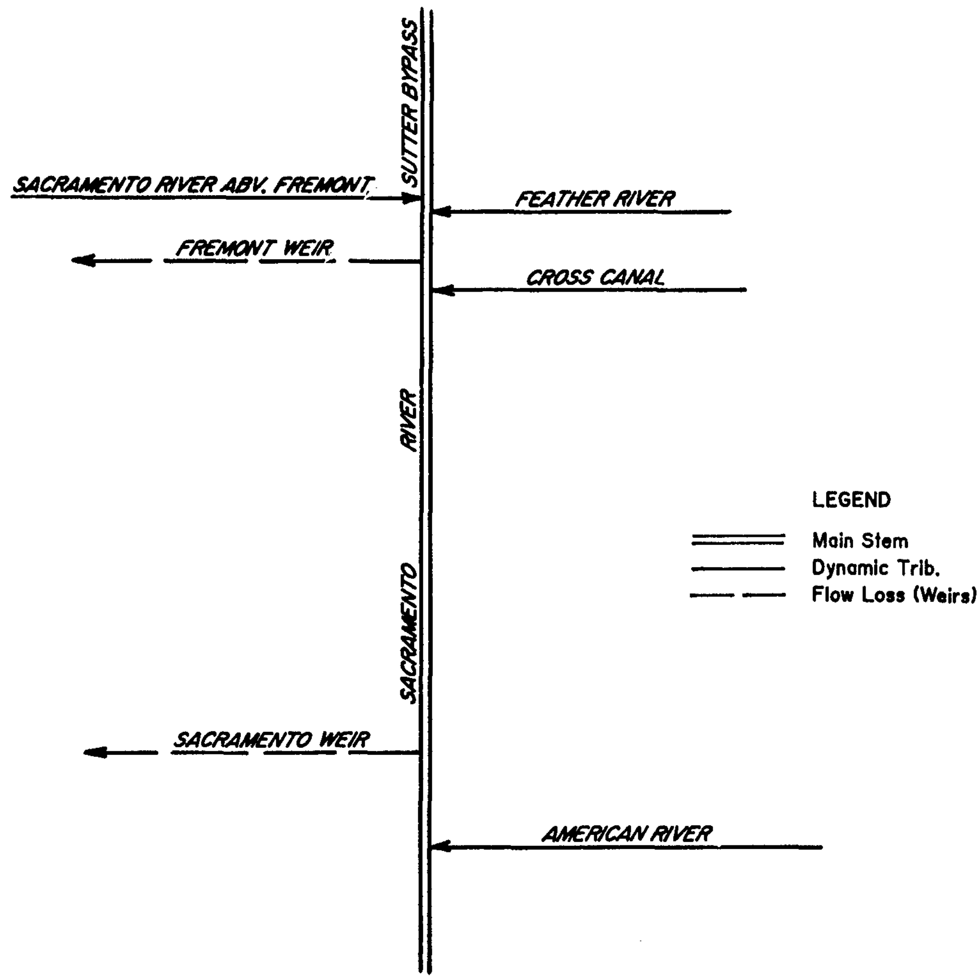
Prepared: J.H.
Drawn: C.A.P.
Date: JANUARY 1990

SHEET 2 OF 3 CHART 27

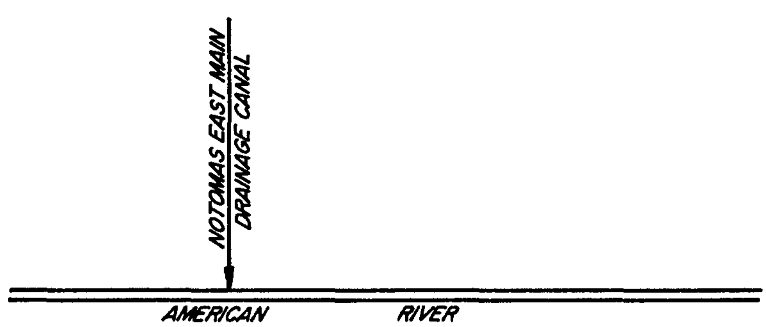


SHEET 3 OF 3 CHART 27

SACRAMENTO RIVER MODEL



AMERICAN RIVER MODEL



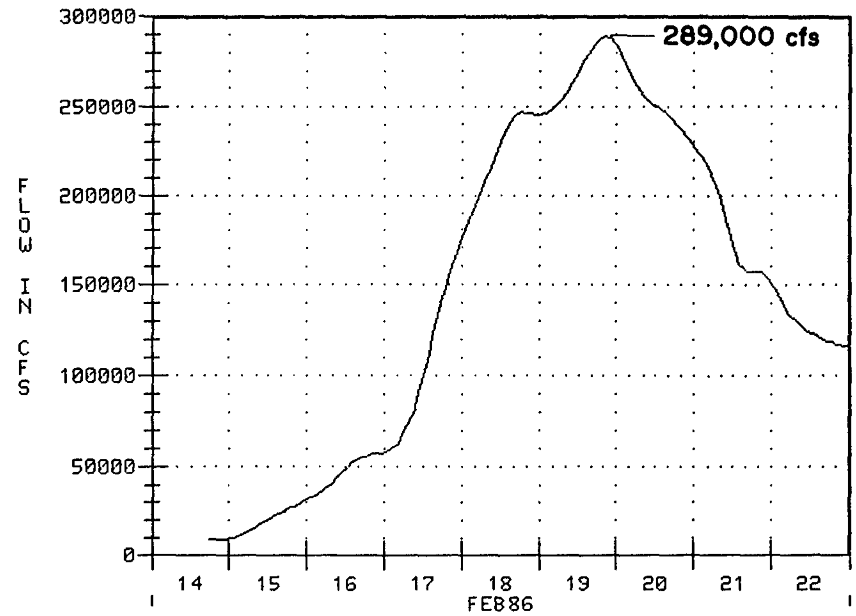
AMERICAN RIVER AND SACRAMENTO
METRO INVESTIGATIONS, CALIFORNIA

SCHEMATIC DIAGRAM

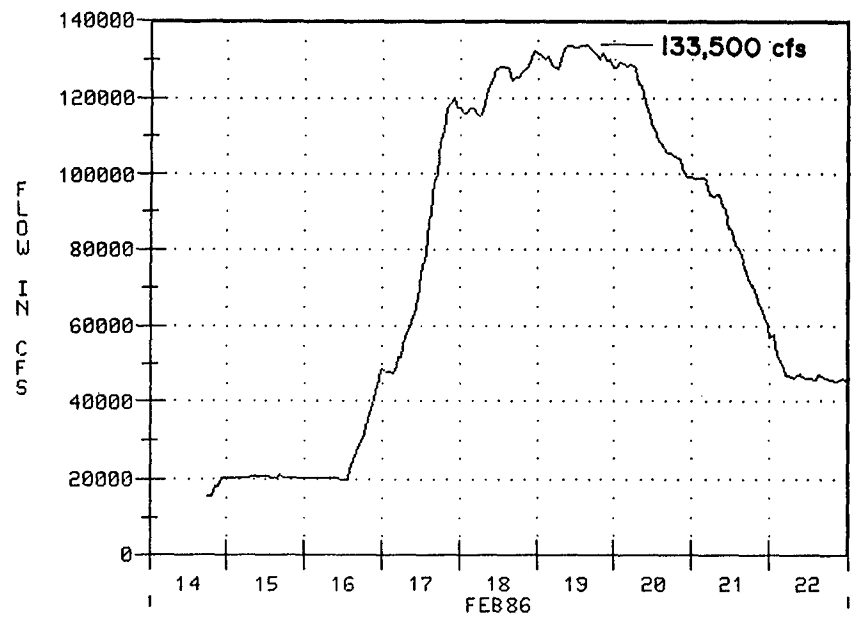
CORPS OF ENGINEERS. SACRAMENTO. CALIFORNIA

Prepared: J.H.
Drawn: C.A.P.
Date: JANUARY 1990

CHART 28



FEATHER RIVER D/S BEAR RIVER



AMERICAN RIVER @ FAIR OAKS

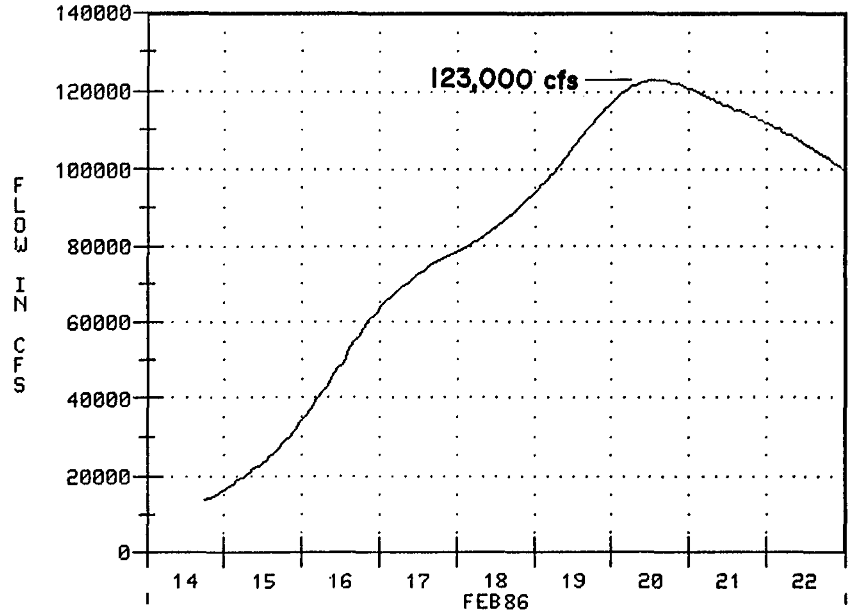
AMERICAN RIVER AND SACRAMENTO
METRO INVESTIGATIONS, CALIFORNIA

1986 OBSERVED HYDROGRAPHS

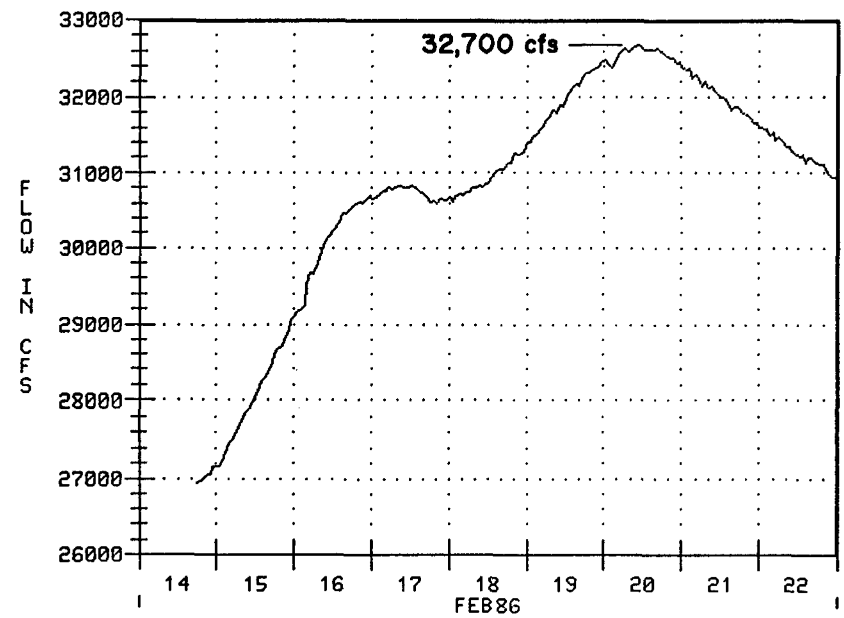
CORPS OF ENGINEERS. SACRAMENTO. CALIFORNIA

Prepared: J.H.
Drawn: C.A.P.
Date: JANUARY 1990

SHEET 1 OF 2 CHART 29



SUTTER BYPASS BELOW TISDALE WEIR



SACRAMENTO RIVER @ WILKINS SL.

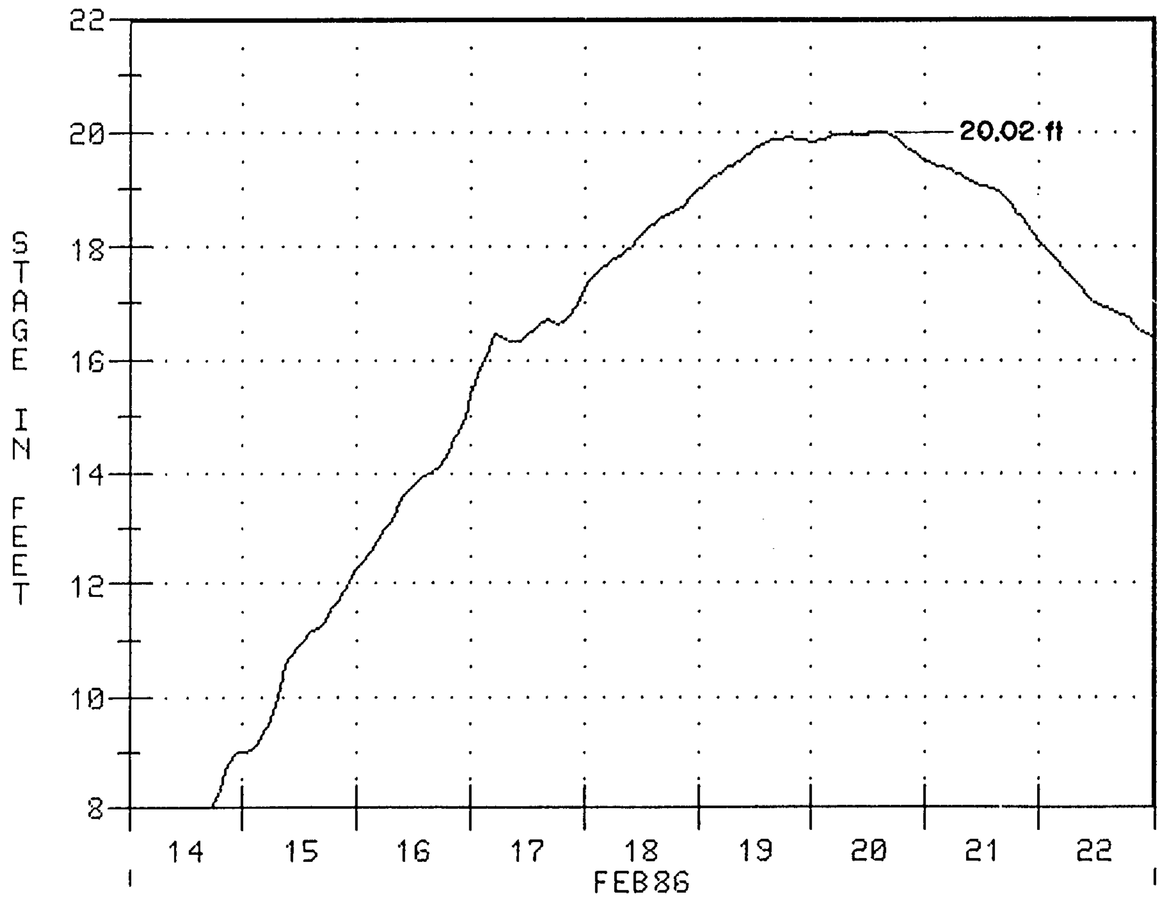
AMERICAN RIVER AND SACRAMENTO
METRO INVESTIGATIONS, CALIFORNIA

1986 OBSERVED HYDROGRAPHS

CORPS OF ENGINEERS, SACRAMENTO, CALIFORNIA

Prepared: J.H.
Drawn: C.A.P.

Date: JANUARY 1990



AMERICAN RIVER AND SACRAMENTO
METRO INVESTIGATIONS, CALIFORNIA

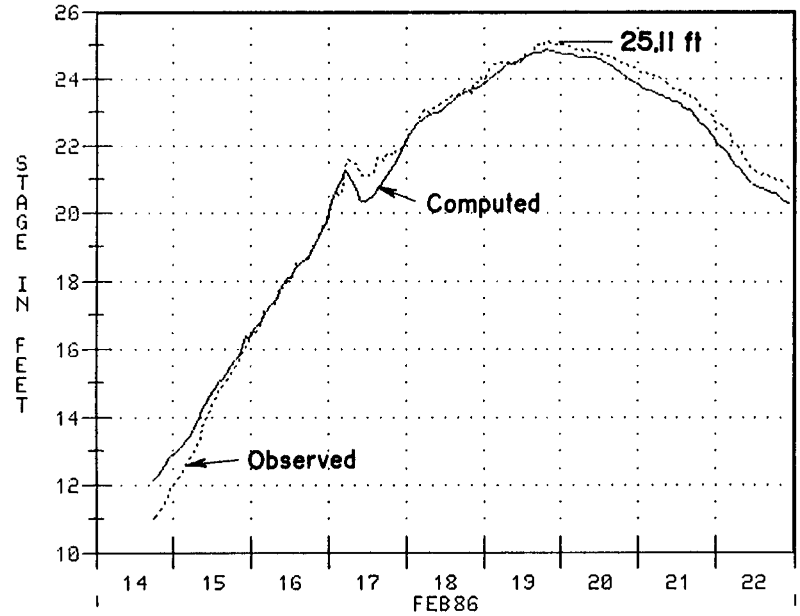
1986 OBSERVED HYDROGRAPH

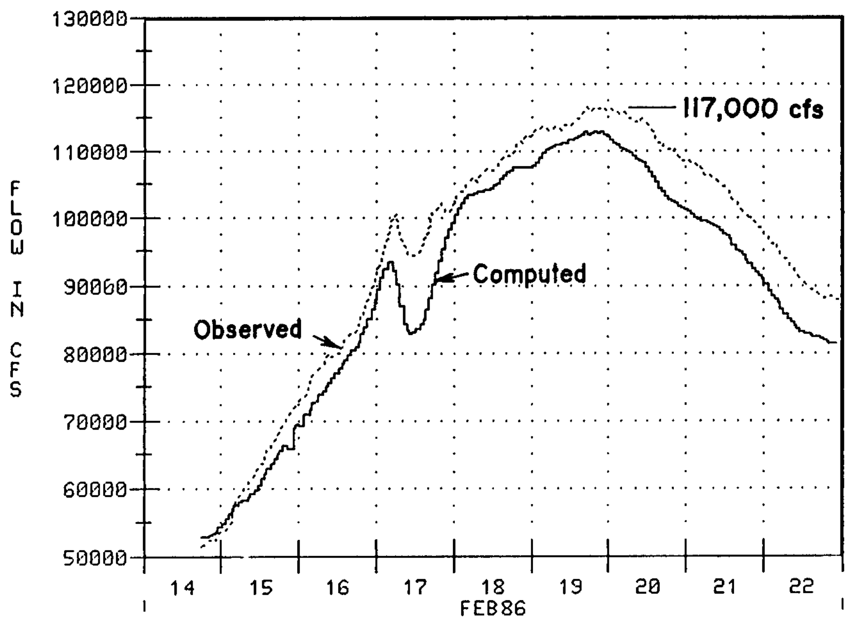
SACRAMENTO RIVER @ SNODGRASS SL.

CORPS OF ENGINEERS, SACRAMENTO, CALIFORNIA

Prepared: J.H.
Drawn: C.A.P.
Date: JANUARY 1990

SHEET 1 OF 11 CHART 30





AMERICAN RIVER AND SACRAMENTO
METRO INVESTIGATIONS, CALIFORNIA

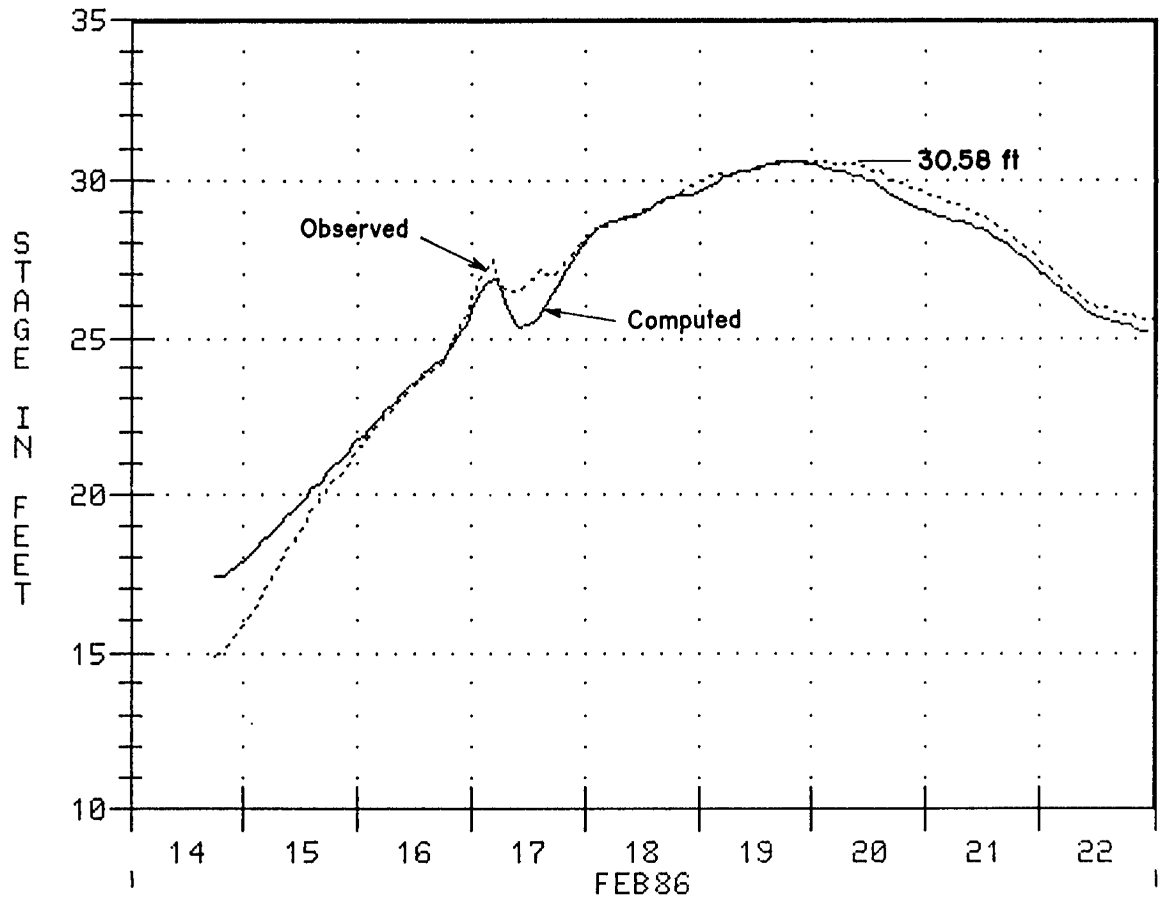
1986 COMPUTED & OBSERVED HYDROGRAPHS

SACRAMENTO RIVER @ FREEPORT

CORPS OF ENGINEERS, SACRAMENTO, CALIFORNIA

Prepared: J.H.
Drawn: C.A.P.

Date: JANUARY 1990



AMERICAN RIVER AND SACRAMENTO
METRO INVESTIGATIONS, CALIFORNIA

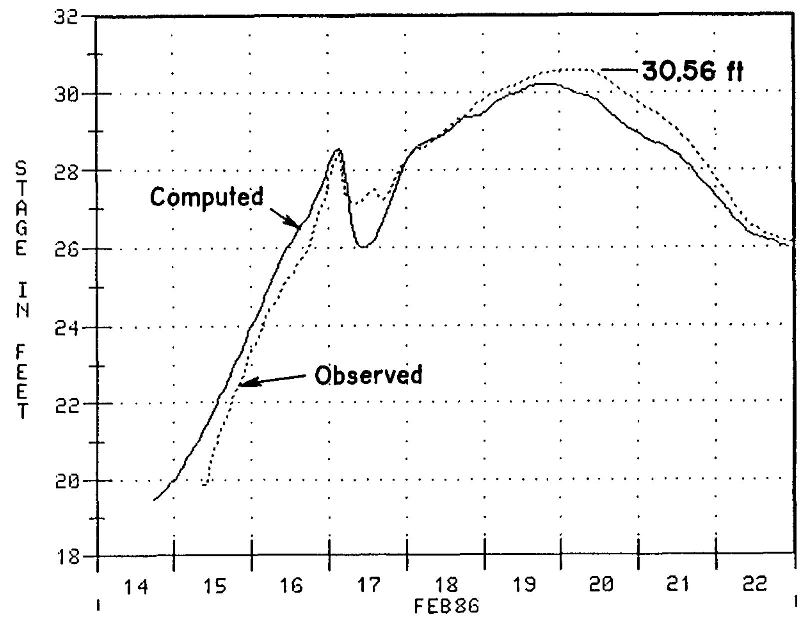
1986 COMPUTED & OBSERVED HYDROGRAPHS

SACRAMENTO RIVER @ "I" STREET

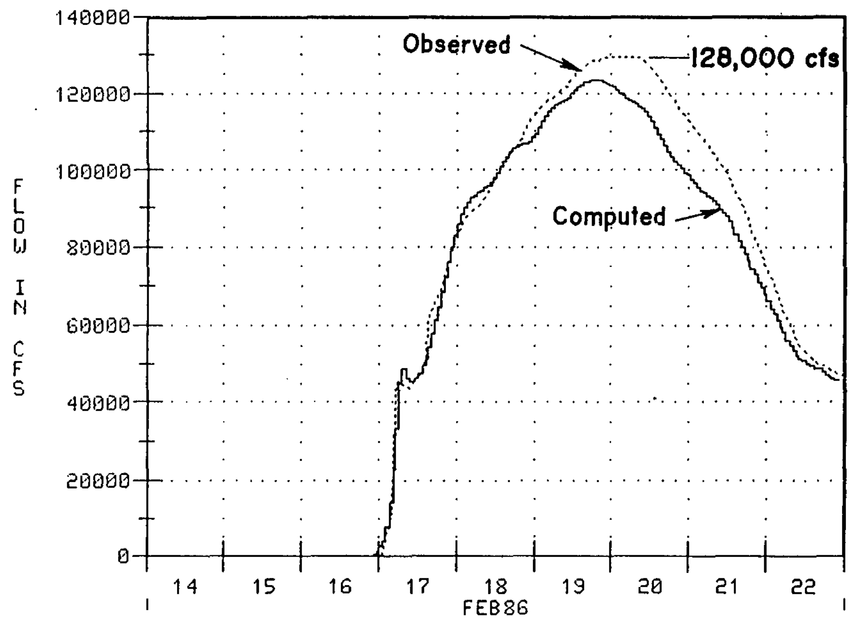
CORPS OF ENGINEERS. SACRAMENTO. CALIFORNIA

Prepared: J.H.
Drawn: C.A.P.
Date: JANUARY 1990

SHEET 3 OF 11 CHART 30



SACRAMENTO R. @ U/S END OF SAC WEIR



SACRAMENTO WEIR SPILL TO YOLO BYPASS

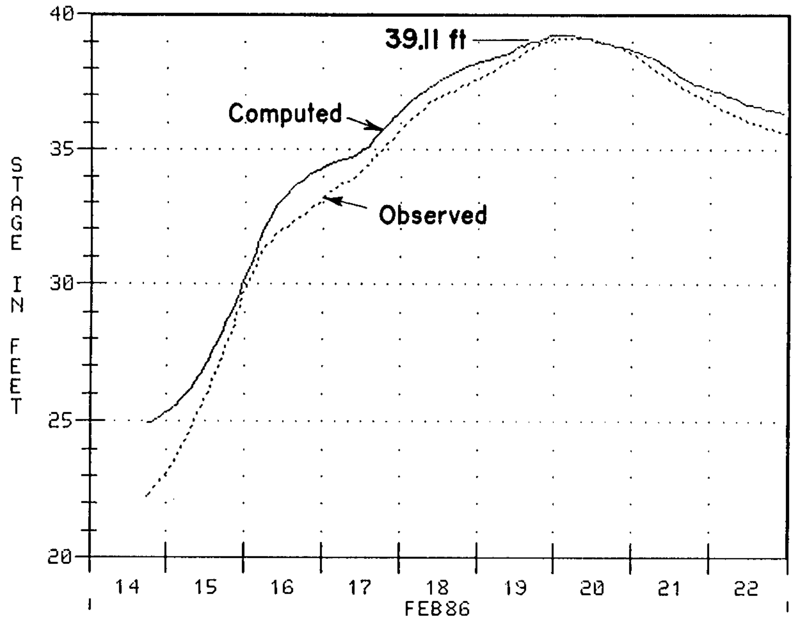
AMERICAN RIVER AND SACRAMENTO
METRO INVESTIGATIONS, CALIFORNIA

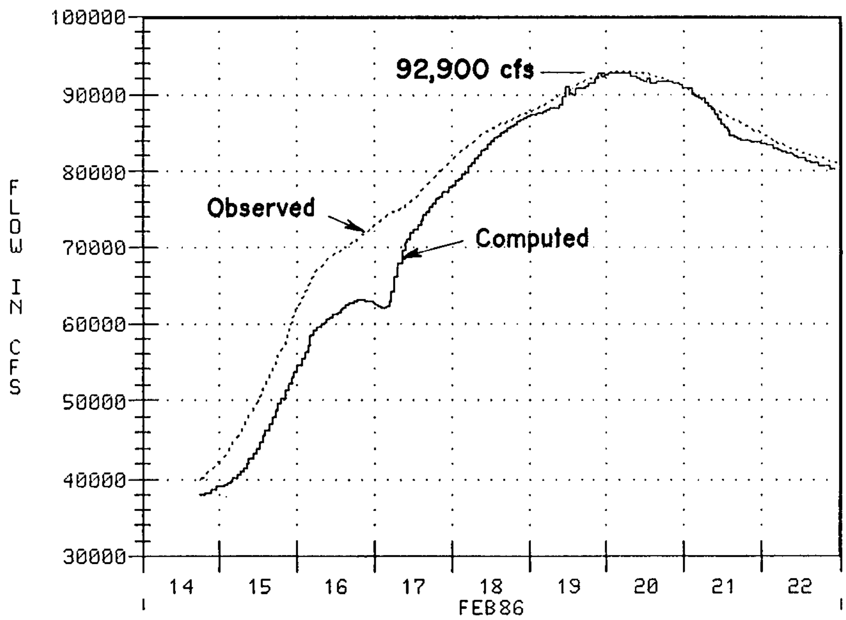
1986 COMPUTED & OBSERVED
HYDROGRAPHS

CORPS OF ENGINEERS. SACRAMENTO. CALIFORNIA

Prepared: J.H.
Drawn: C.A.P.

Date: JANUARY 1990





AMERICAN RIVER AND SACRAMENTO
METRO INVESTIGATIONS, CALIFORNIA

1986 COMPUTED & OBSERVED HYDROGRAPHS

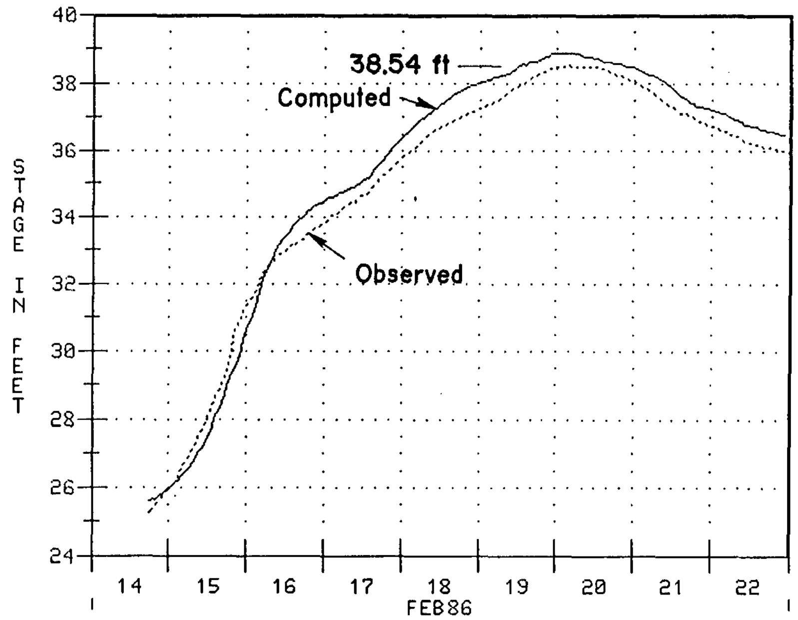
SACRAMENTO RIVER @ VERONA

CORPS OF ENGINEERS, SACRAMENTO, CALIFORNIA

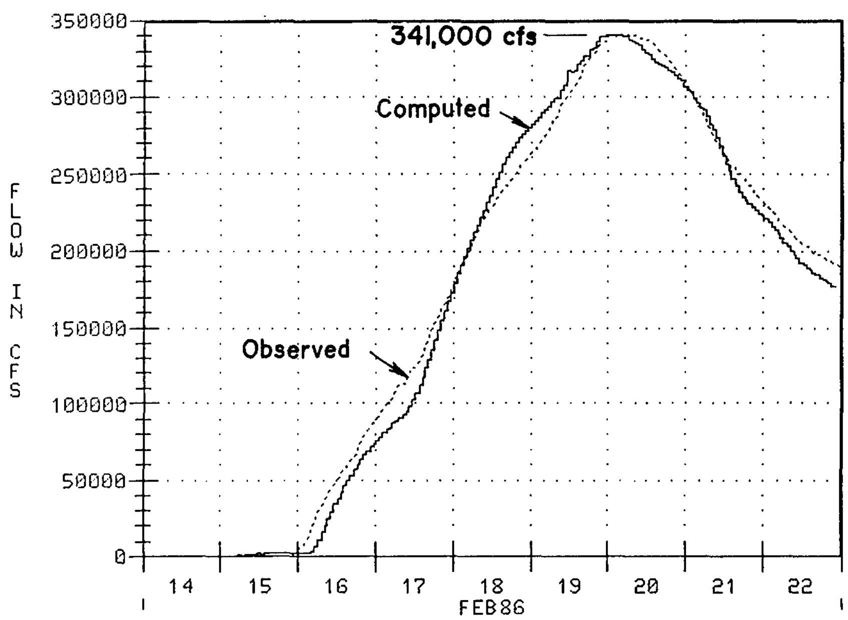
Prepared: J.H.
Drawn: C.A.P.

Date: JANUARY 1990

SHEET 5 OF 11 CHART 30



SACRAMENTO RIVER @ FREMONT WEIR WEST END



FREMONT SPILL TO YOLO BYPASS

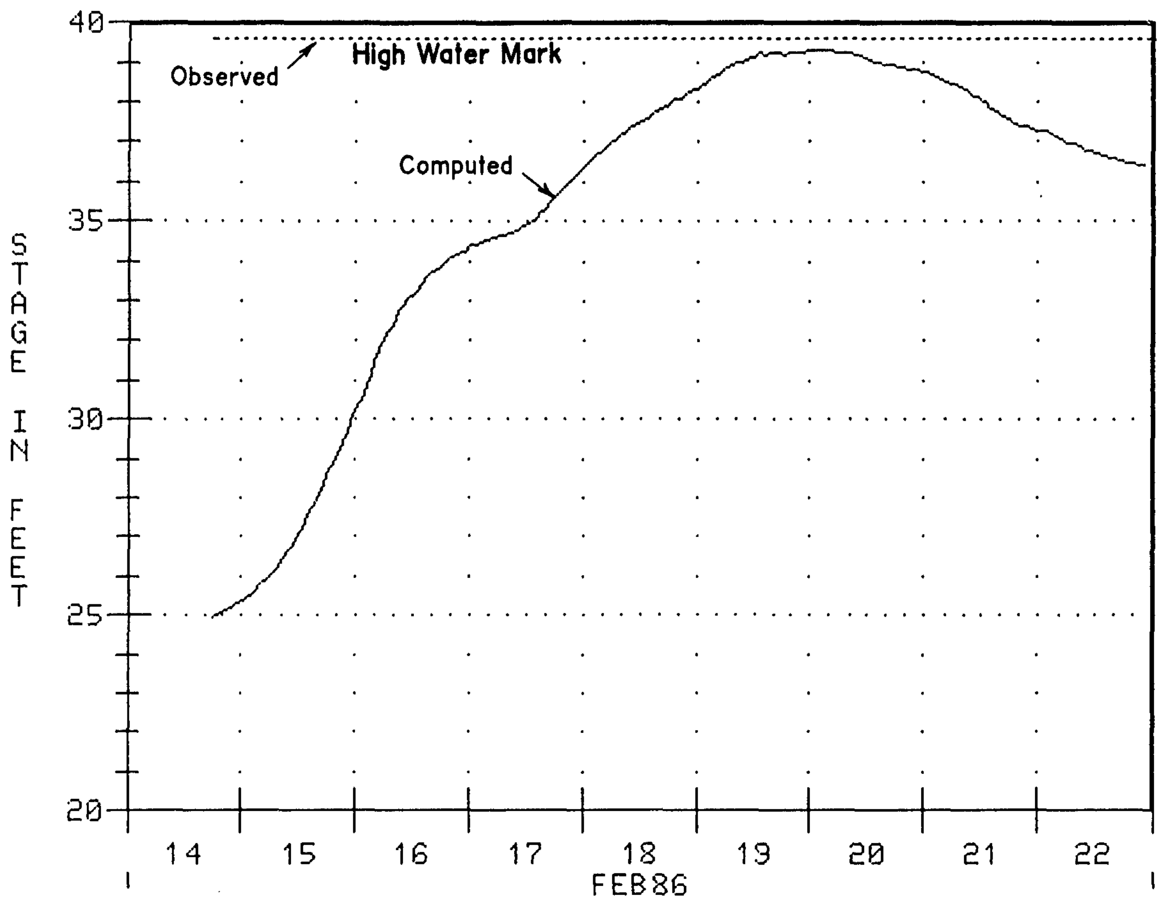
AMERICAN RIVER AND SACRAMENTO METRO INVESTIGATIONS, CALIFORNIA

1986 COMPUTED & OBSERVED HYDROGRAPHS

CORPS OF ENGINEERS, SACRAMENTO, CALIFORNIA

Prepared: J.H.
Drawn: C.A.P.
Date: JANUARY 1990

SHEET 6 OF 11 CHART 30



AMERICAN RIVER AND SACRAMENTO
METRO INVESTIGATIONS, CALIFORNIA

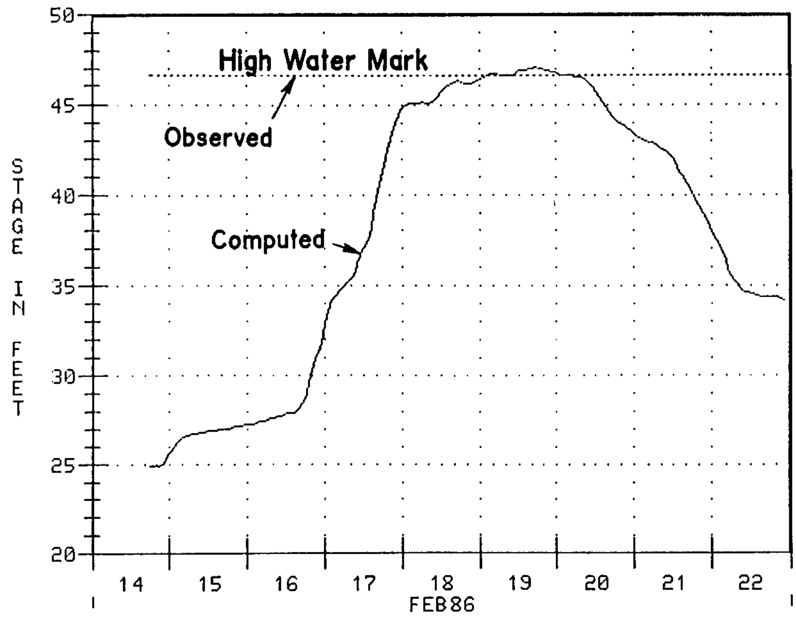
1986 COMPUTED & OBSERVED HYDROGRAPHS

CROSS CANAL @ HY. 99

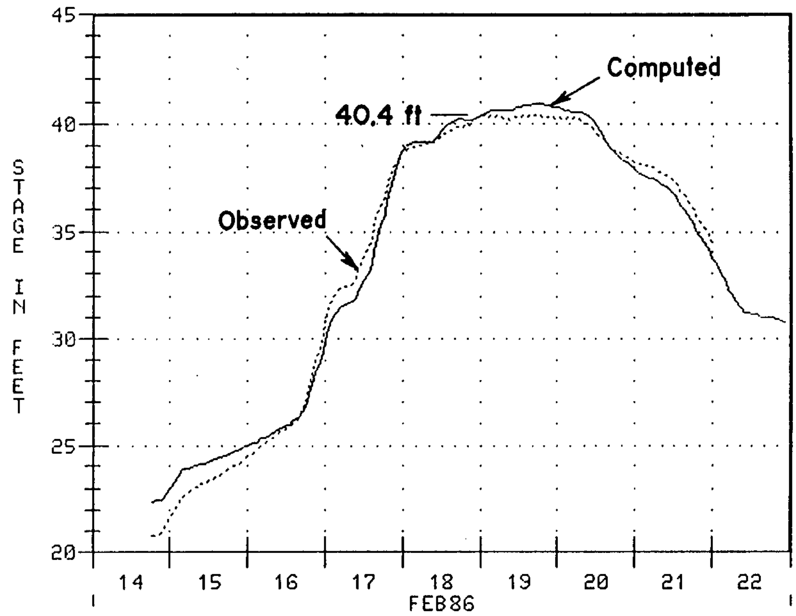
CORPS OF ENGINEERS, SACRAMENTO, CALIFORNIA

Prepared: J.H.
Drawn: C.A.P.
Date: JANUARY 1990

SHEET 7 OF 11 CHART 30



@ WATT AVE.



@ H STREET

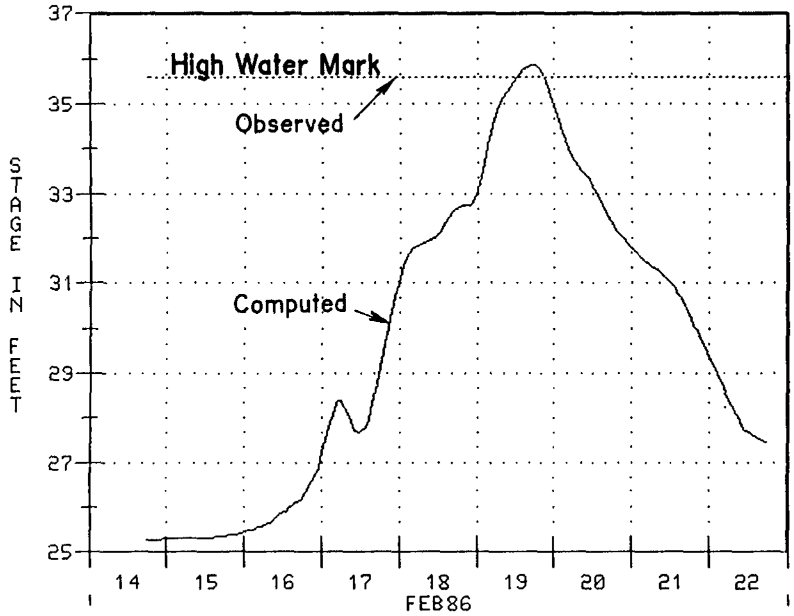
AMERICAN RIVER AND SACRAMENTO
METRO INVESTIGATIONS, CALIFORNIA

1986 COMPUTED & OBSERVED HYDROGRAPHS

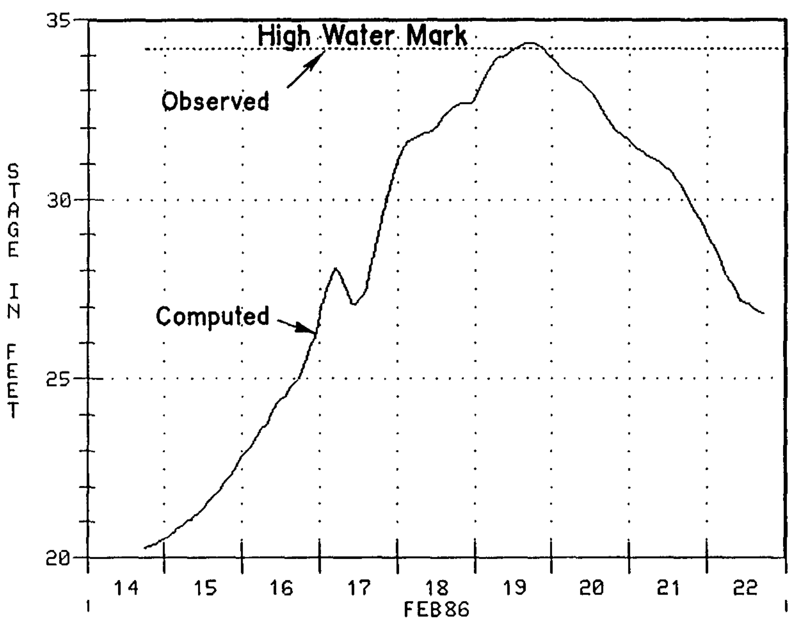
AMERICAN RIVER

CORPS OF ENGINEERS, SACRAMENTO, CALIFORNIA

Prepared: J.H.
Drawn: C.A.P.
Date: JANUARY 1990



@ MAIN AVE.



@ EL CAMINO

AMERICAN RIVER AND SACRAMENTO
METRO INVESTIGATIONS, CALIFORNIA

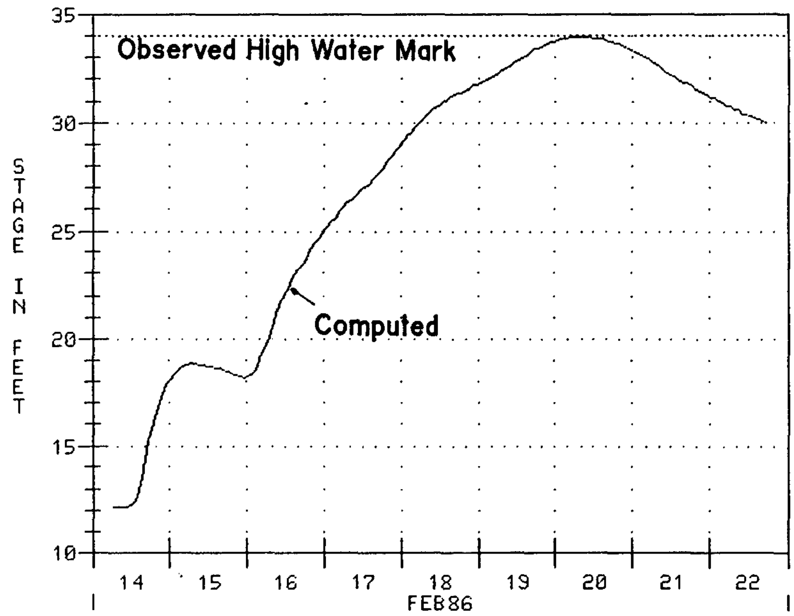
1986 COMPUTED & OBSERVED HYDROGRAPHS

NATOMAS EAST MAIN DRAINAGE CANAL

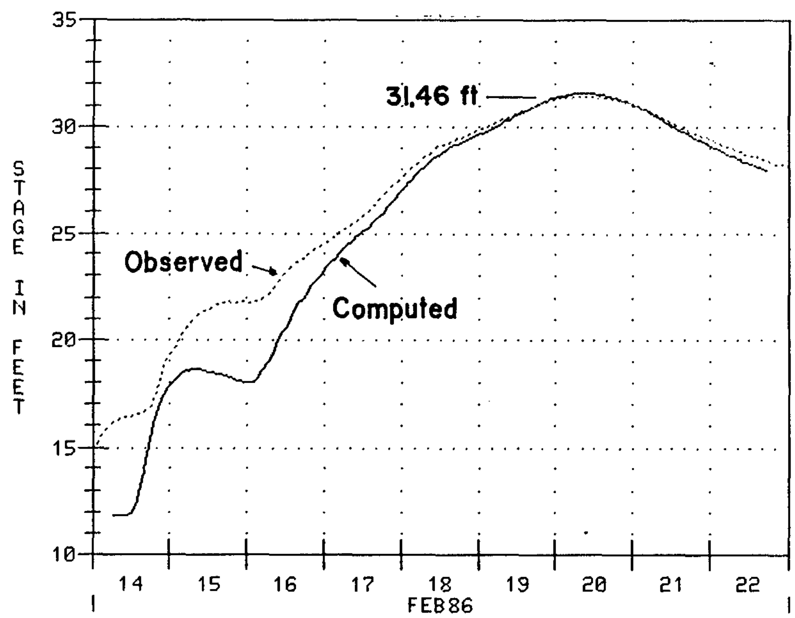
CORPS OF ENGINEERS, SACRAMENTO, CALIFORNIA

Prepared: J.H.
Drawn: C.A.P.
Date: JANUARY 1990

SHEET 9 OF 11 CHART 30



AT KNIGHTS LANDINGS RIDGE CUT



AT WOODLAND

AMERICAN RIVER AND SACRAMENTO
METRO INVESTIGATIONS, CALIFORNIA

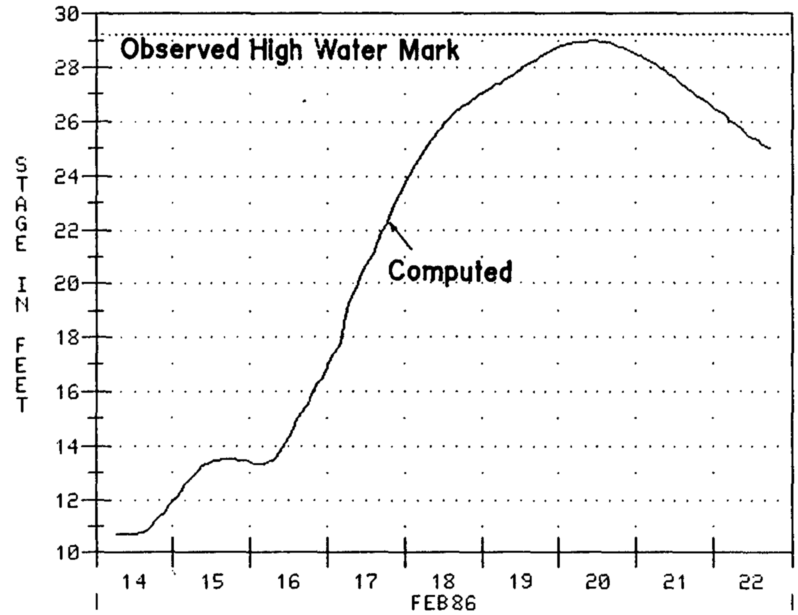
1986 COMPUTED & OBSERVED
HYDROGRAPHS

YOLO BYPASS

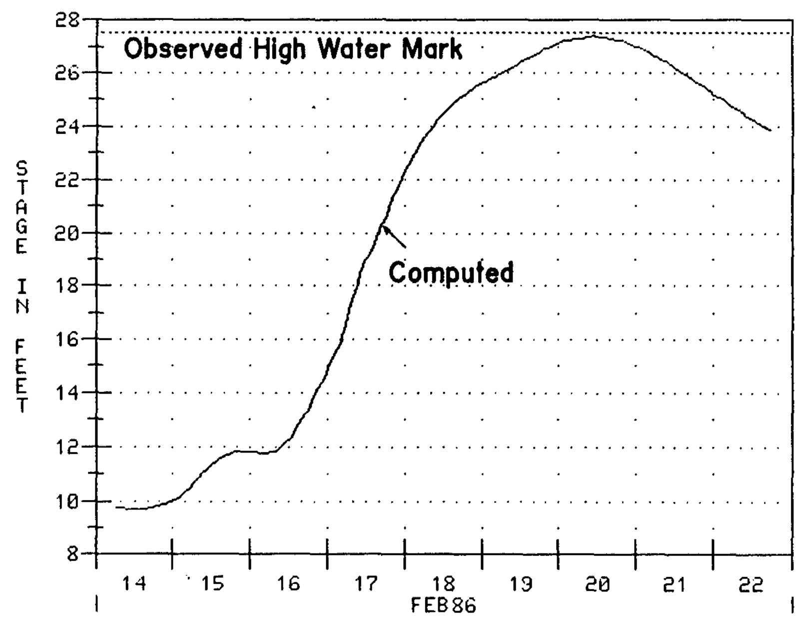
CORPS OF ENGINEERS. SACRAMENTO. CALIFORNIA

Prepared: J.H.
Drawn: J.H.
Date: JANUARY 1990

SHEET 10 OF 11 CHART 30



AT D/S END OF SACRAMENTO BYPASS



AT SHIP CHANNEL

AMERICAN RIVER AND SACRAMENTO
METRO INVESTIGATIONS, CALIFORNIA

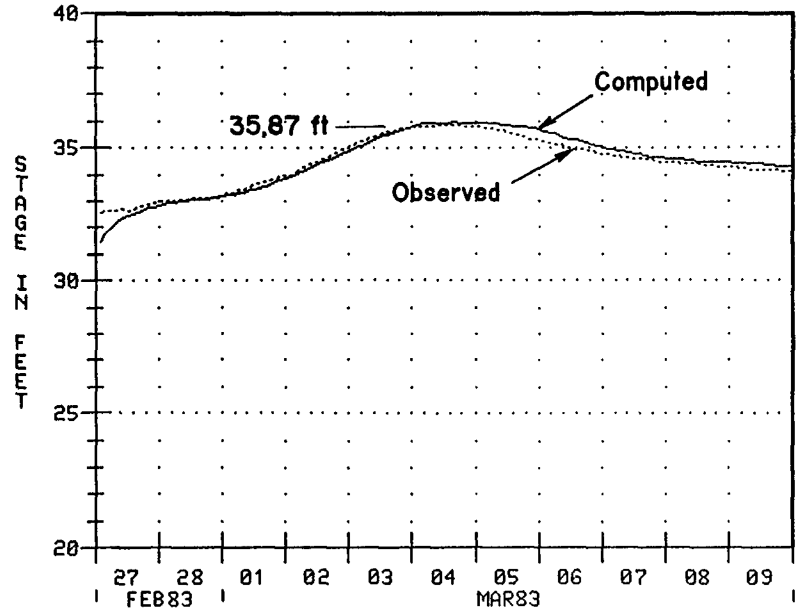
1986 COMPUTED & OBSERVED
HYDROGRAPHS

YOLO BYPASS

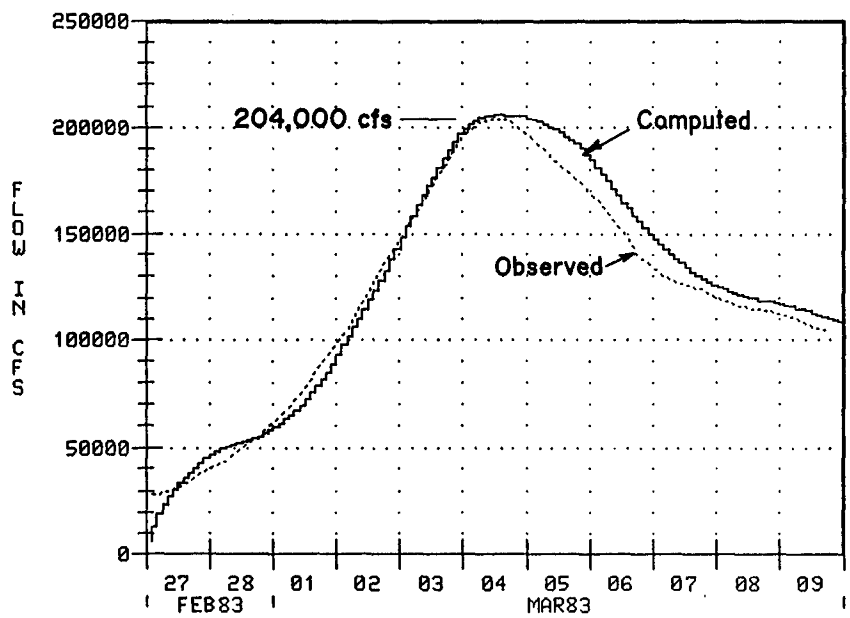
CORPS OF ENGINEERS. SACRAMENTO. CALIFORNIA

Prepared: J.H.
Drawn: J.H.
Date: JANUARY 1990

SHEET 11 OF 11 CHART 30



SACRAMENTO RIVER @ FREMONT WEIR WEST END



FREMONT WEIR SPILL TO YOLO BYPASS

AMERICAN RIVER AND SACRAMENTO
METRO INVESTIGATIONS, CALIFORNIA

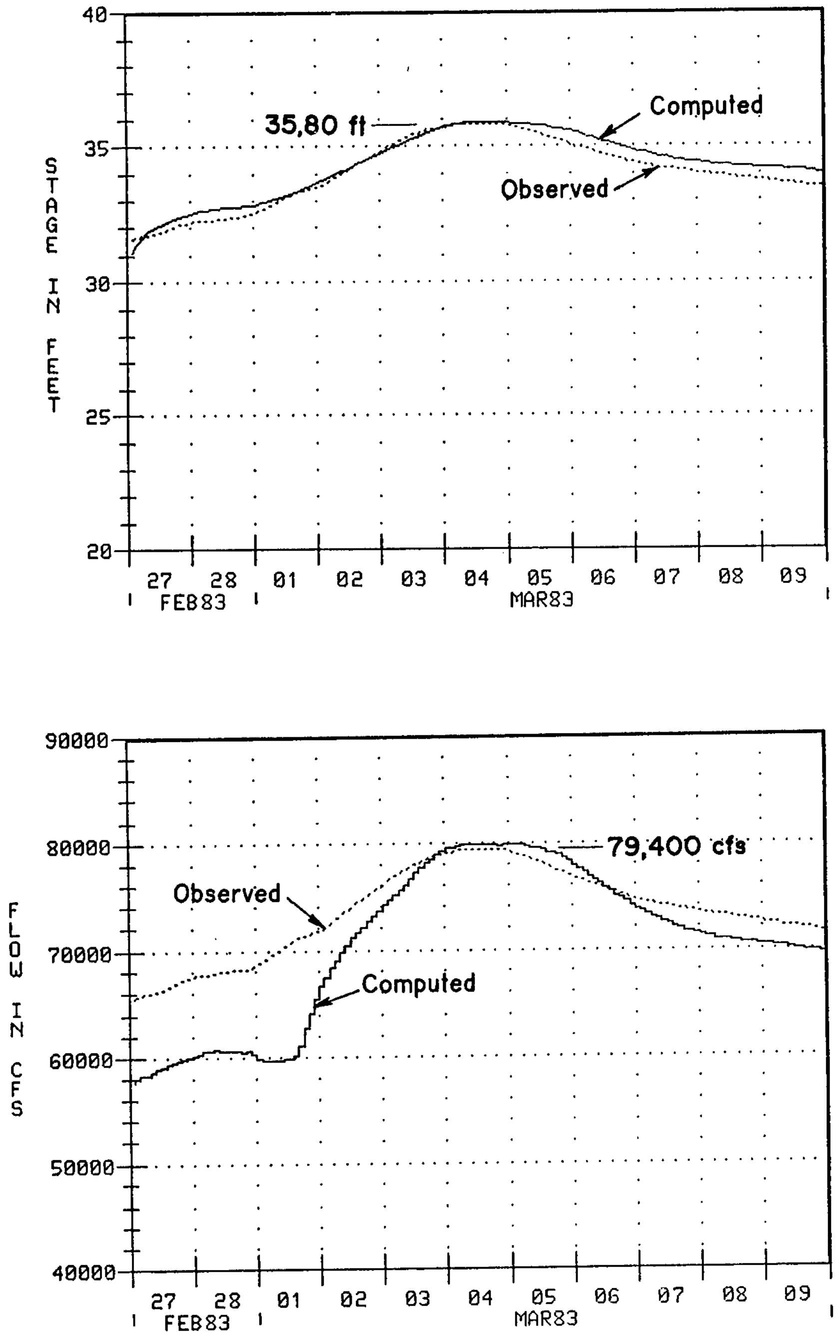
1983 COMPUTED & OBSERVED
HYDROGRAPHS

CORPS OF ENGINEERS, SACRAMENTO, CALIFORNIA

Prepared: J.H.
Drawn: C.A.P.

Date: JANUARY 1990

SHEET 1 OF 5 CHART 31



AMERICAN RIVER AND SACRAMENTO
METRO INVESTIGATIONS, CALIFORNIA

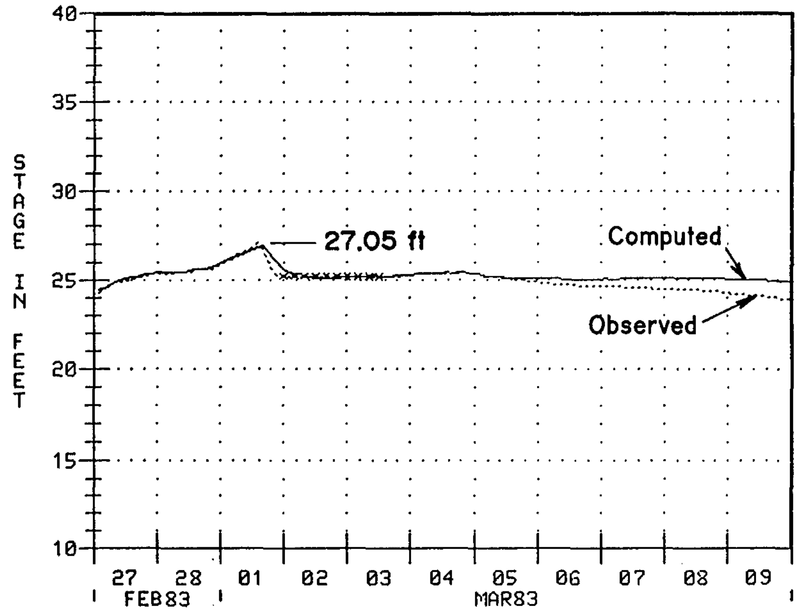
1983 COMPUTED & OBSERVED HYDROGRAPHS

SACRAMENTO RIVER @ VERONA

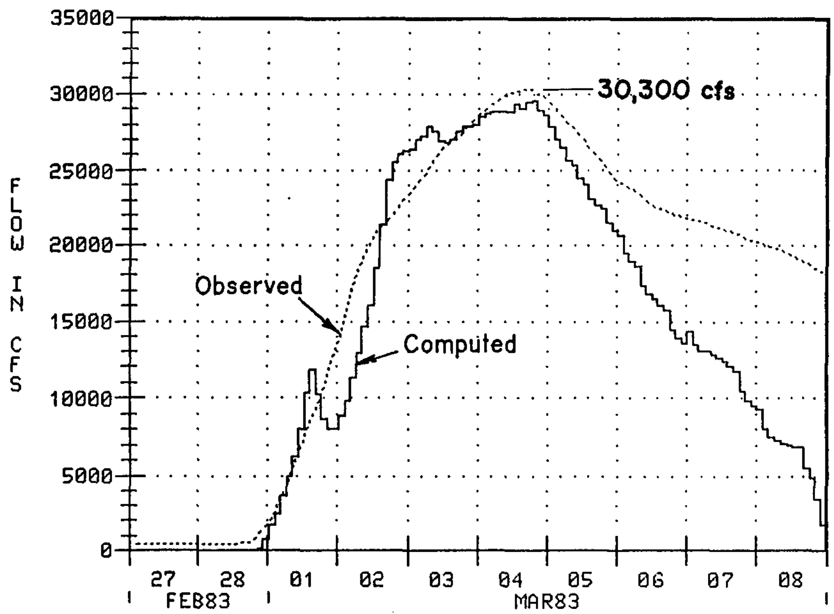
CORPS OF ENGINEERS. SACRAMENTO. CALIFORNIA

Prepared: J.H.
Drawn: C.A.P.

Date: JANUARY 1990



SACRAMENTO R. @ U/S END OF SACRAMENTO WEIR



SACRAMENTO WEIR SPILL TO YOLO BYPASS

AMERICAN RIVER AND SACRAMENTO
METRO INVESTIGATIONS, CALIFORNIA

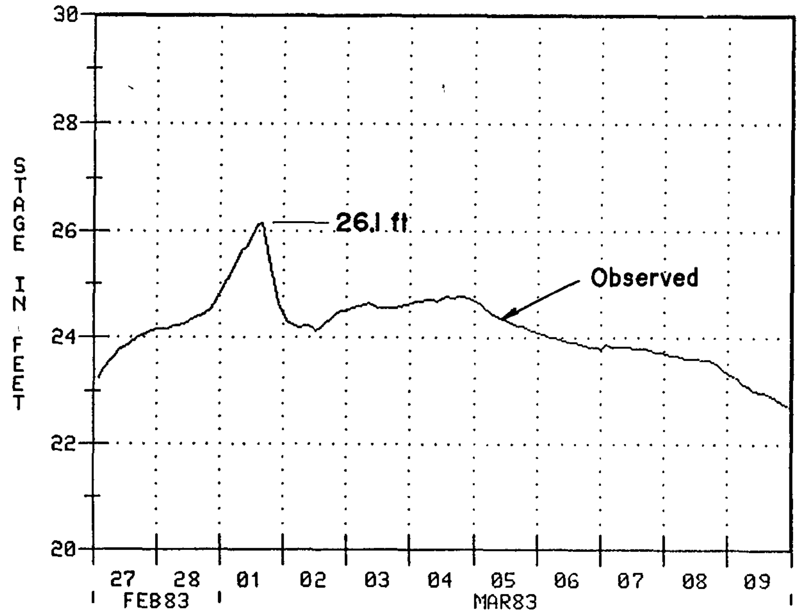
1983 COMPUTED & OBSERVED HYDROGRAPHS

CORPS OF ENGINEERS. SACRAMENTO. CALIFORNIA

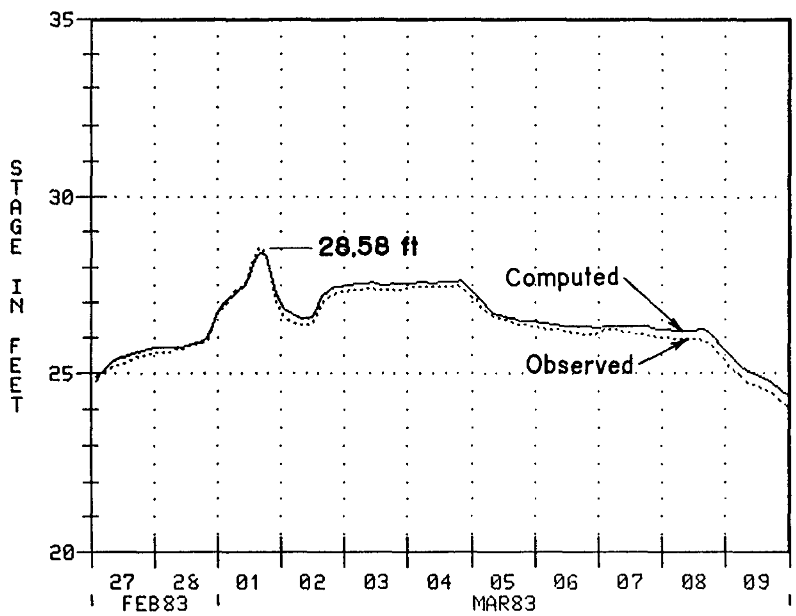
Prepared: J.H.
Drawn: C.A.P.

Date: JANUARY 1990

SHEET 3 OF 5 CHART 31



SACRAMENTO RIVER @ I-STREET



AMERICAN RIVER @ H-STREET

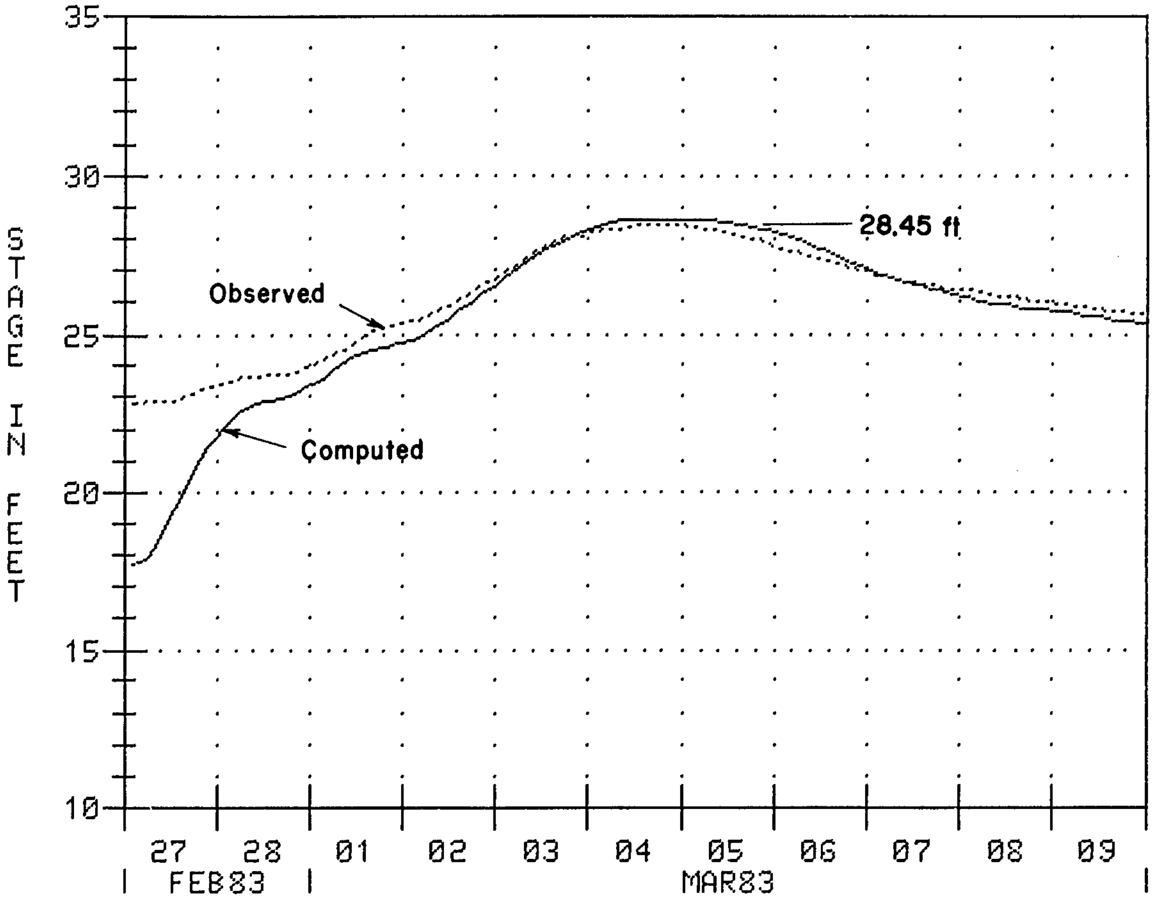
AMERICAN RIVER AND SACRAMENTO METRO INVESTIGATIONS, CALIFORNIA

1983 COMPUTED & OBSERVED HYDROGRAPHS

CORPS OF ENGINEERS, SACRAMENTO, CALIFORNIA

Prepared: J.H.
Drawn: C.A.P.

Date: JANUARY 1990



AMERICAN RIVER AND SACRAMENTO
METRO INVESTIGATIONS, CALIFORNIA

1983 COMPUTED & OBSERVED HYDROGRAPHS

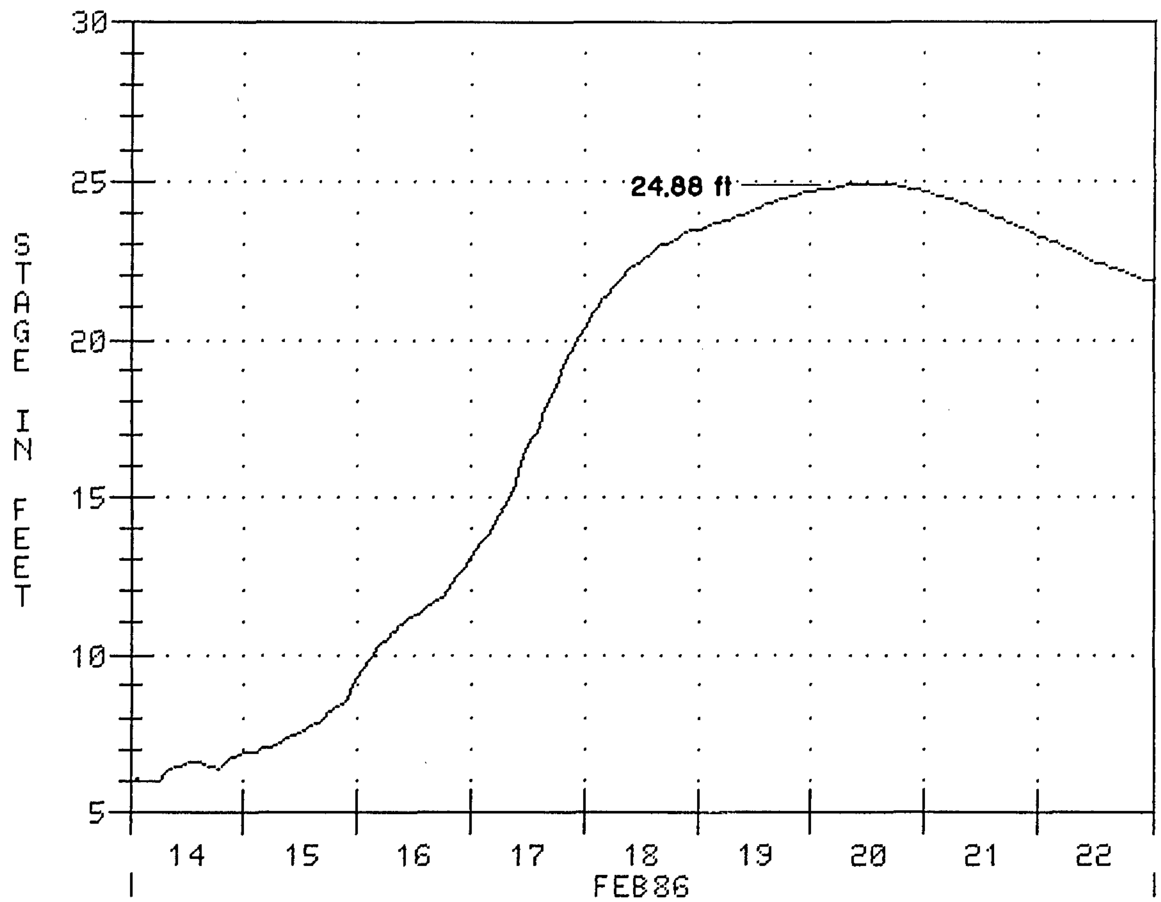
YOLO BYPASS AT WOODLAND

CORPS OF ENGINEERS, SACRAMENTO, CALIFORNIA

Prepared: J.H.
Drawn: C.A.P.

Date: JANUARY 1990

SHEET 5 OF 5 CHART 31



AMERICAN RIVER AND SACRAMENTO
METRO INVESTIGATIONS, CALIFORNIA

1986 OBSERVED HYDROGRAPH

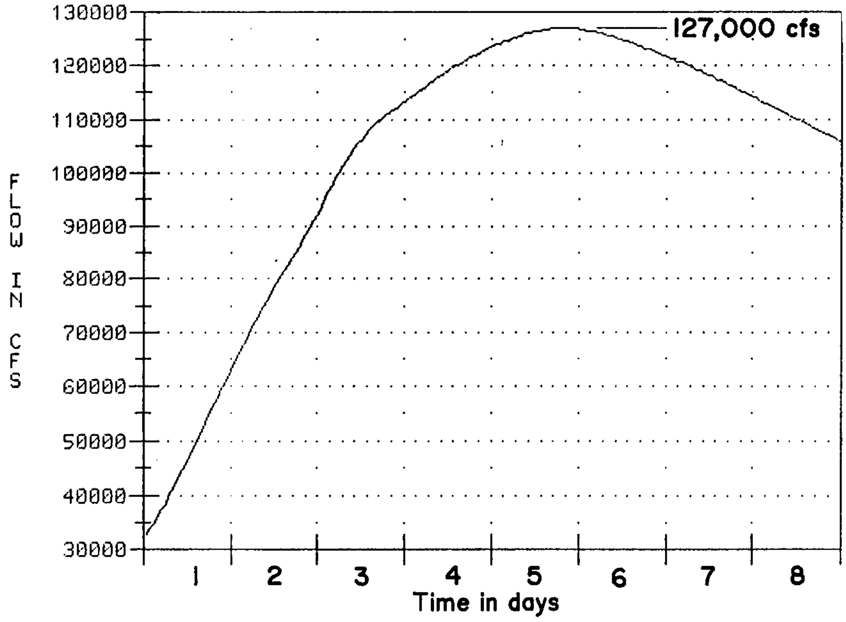
YOLO BYPASS AT LISBON

CORPS OF ENGINEERS, SACRAMENTO, CALIFORNIA

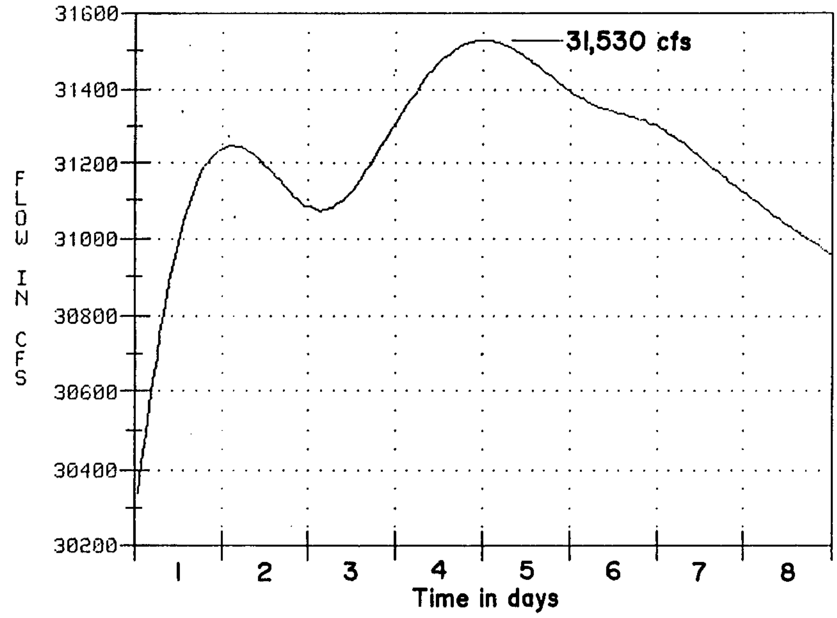
Prepared: J.H.
Drawn: C.A.P.

Date: JANUARY 1990

CHART 32



SUTTER BYPASS D/S TISDALE WEIR



SACRAMENTO RIVER @ WILKINS SL.

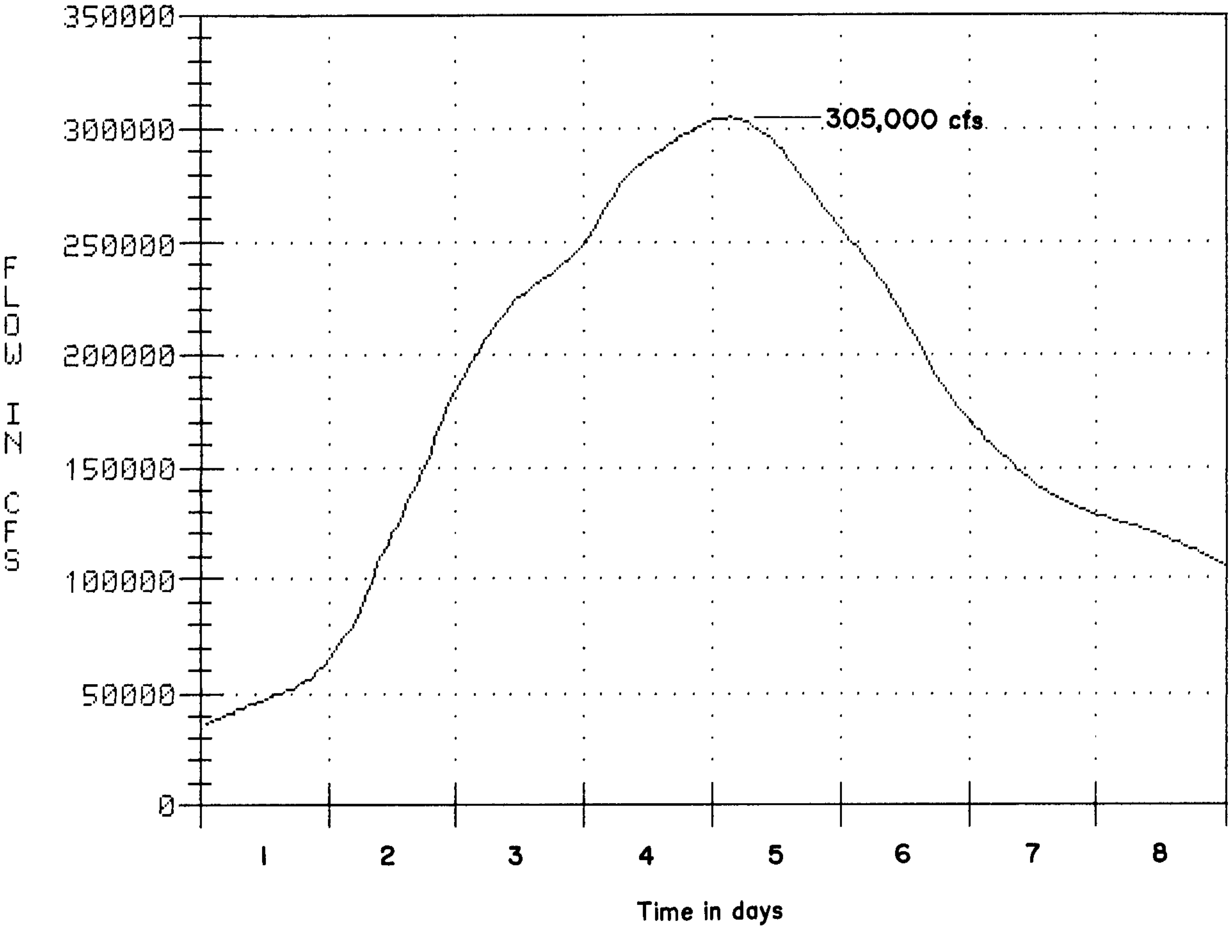
AMERICAN RIVER AND SACRAMENTO
METRO INVESTIGATIONS, CALIFORNIA

100-YR. COMPUTED HYDROGRAPH

CORPS OF ENGINEERS, SACRAMENTO, CALIFORNIA

Prepared: J.H.
Drawn: C.A.P.
Date: JANUARY 1990

SHEET 1 OF 3 CHART 33



AMERICAN RIVER AND SACRAMENTO
METRO INVESTIGATIONS, CALIFORNIA

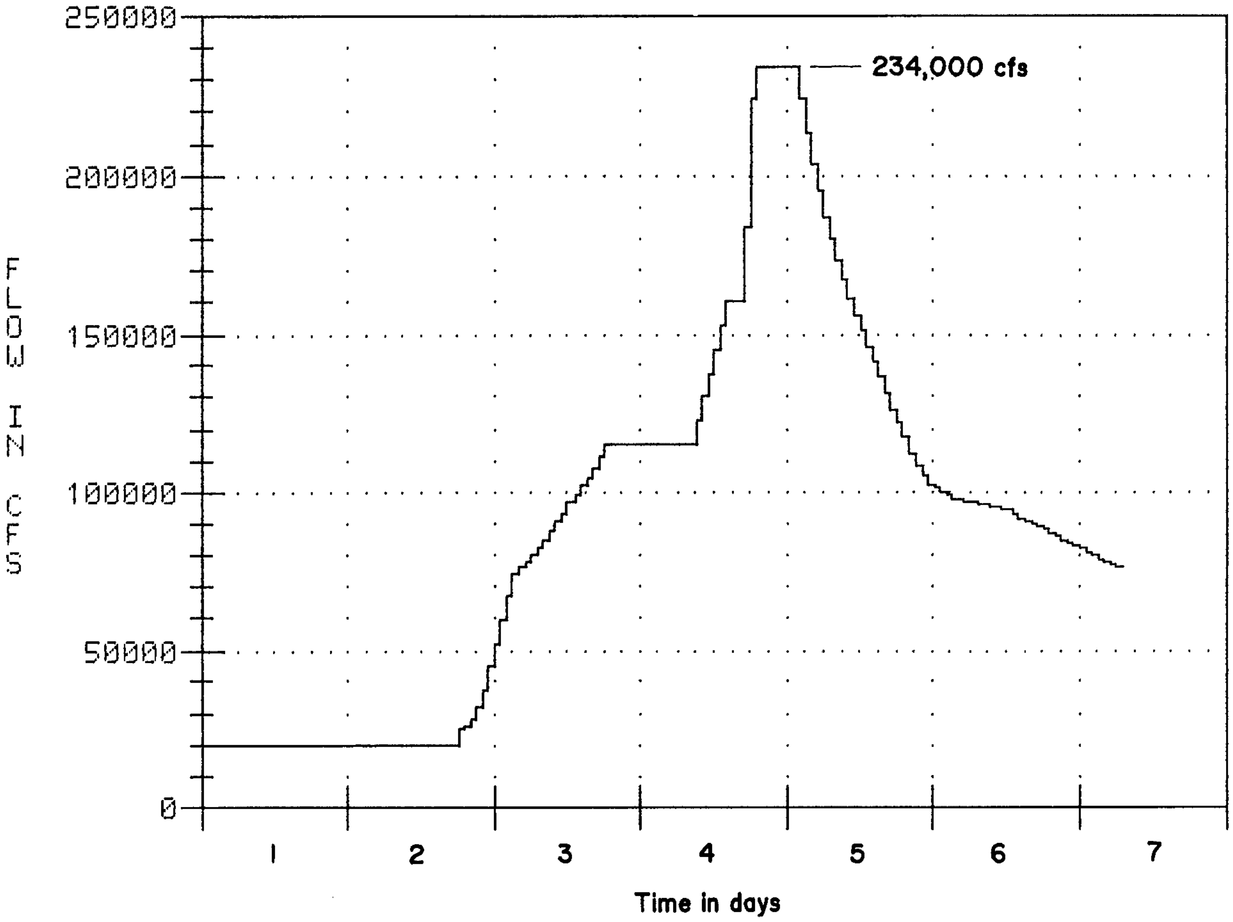
100-YR. COMPUTED HYDROGRAPH

FEATHER RIVER D/S BEAR RIVER

CORPS OF ENGINEERS. SACRAMENTO. CALIFORNIA

Prepared: J.H.
Drawn: C.A.P.
Date: JANUARY 1990

SHEET 2 OF 3 CHART 33



AMERICAN RIVER AND SACRAMENTO
METRO INVESTIGATIONS, CALIFORNIA

100-YR. COMPUTED HYDROGRAPH
PREPROJECT

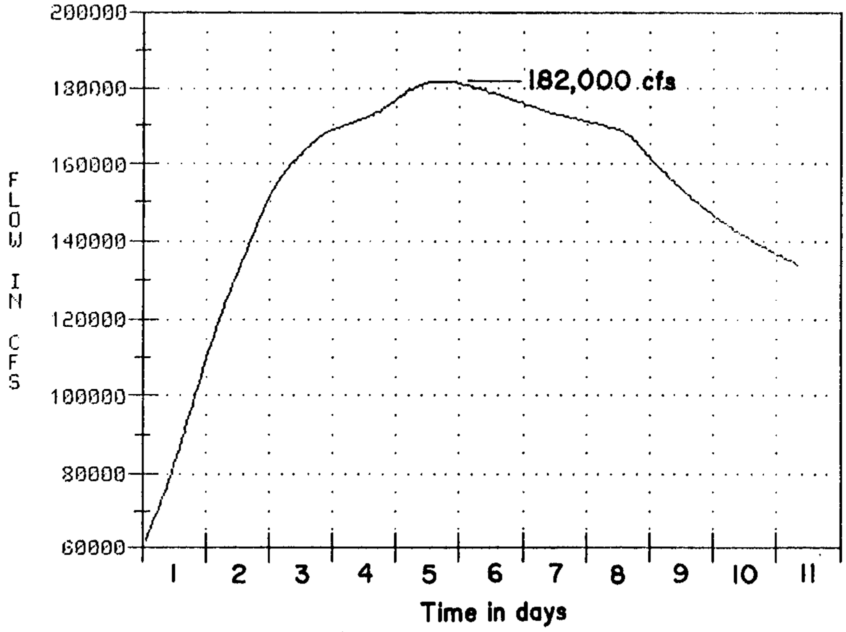
AMERICAN RIVER @ FAIR OAKS

CORPS OF ENGINEERS, SACRAMENTO, CALIFORNIA

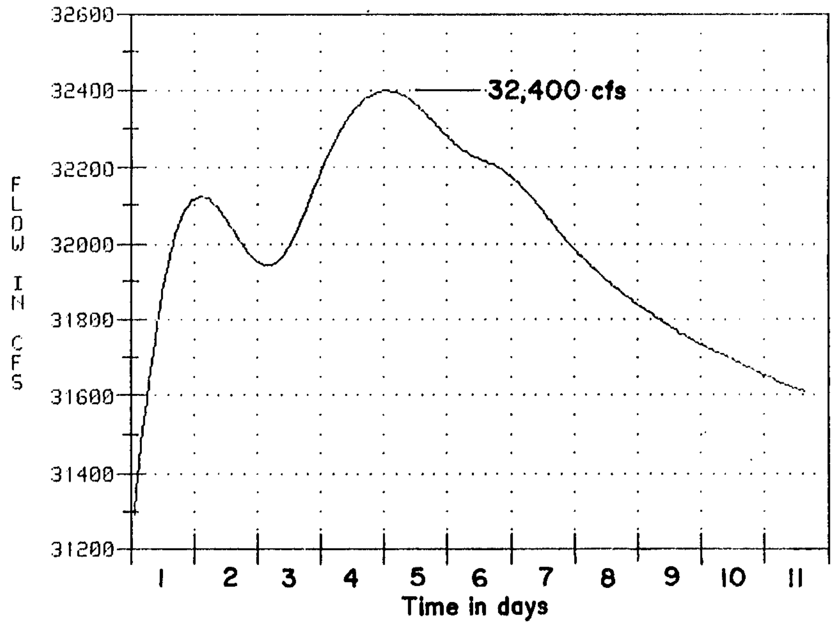
Prepared: J.H.
Drawn: C.A.P.

Date: JANUARY 1990

SHEET 3 OF 3 CHART 33



SUTTER BYPASS D/S TISDALE WEIR



SACRAMENTO RIVER @ WILKINS SL.

AMERICAN RIVER AND SACRAMENTO
METRO INVESTIGATIONS, CALIFORNIA

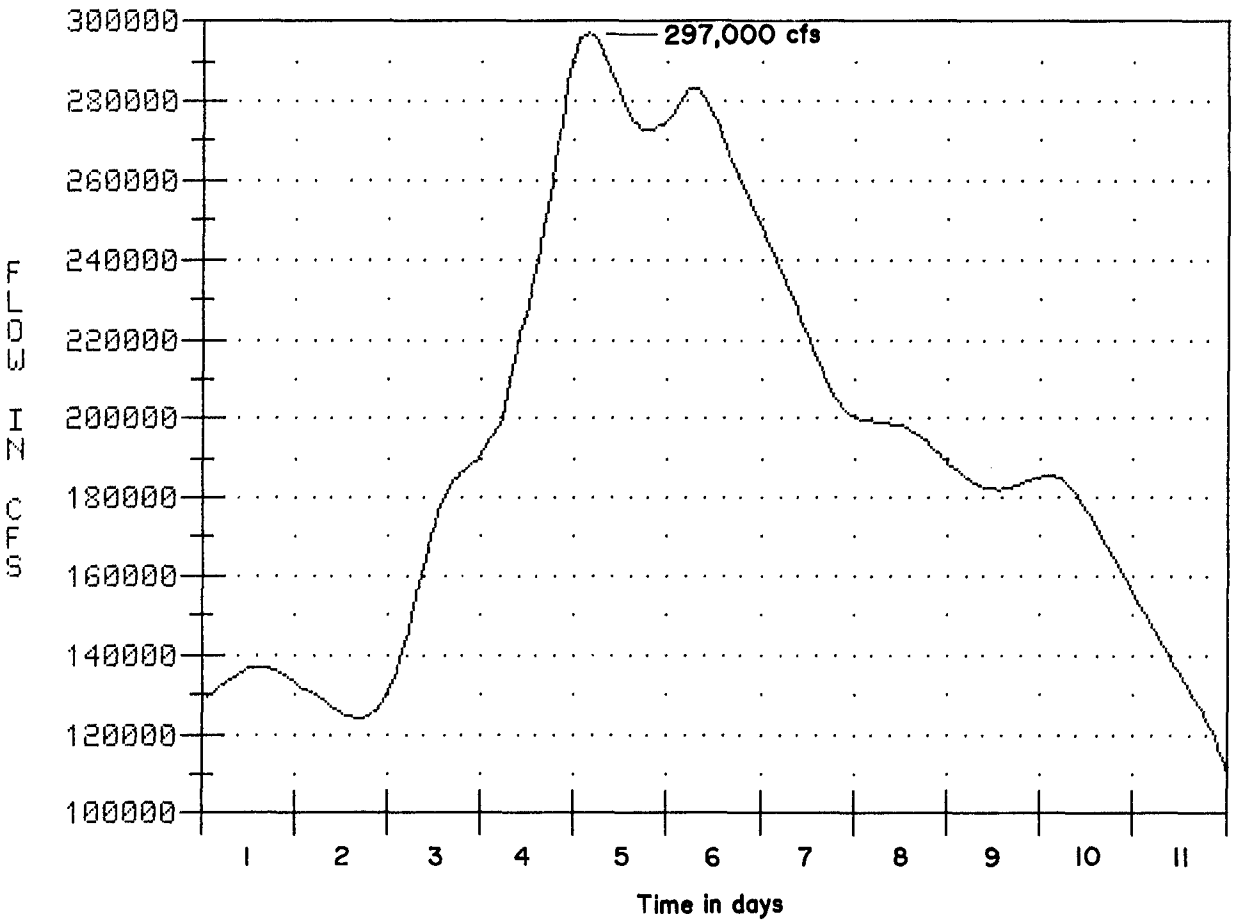
200-YR. COMPUTED HYDROGRAPH

CORPS OF ENGINEERS, SACRAMENTO, CALIFORNIA

Prepared: J.H.
Drawn: C.A.P.

Date: JANUARY 1990

SHEET 1 OF 3 CHART 34



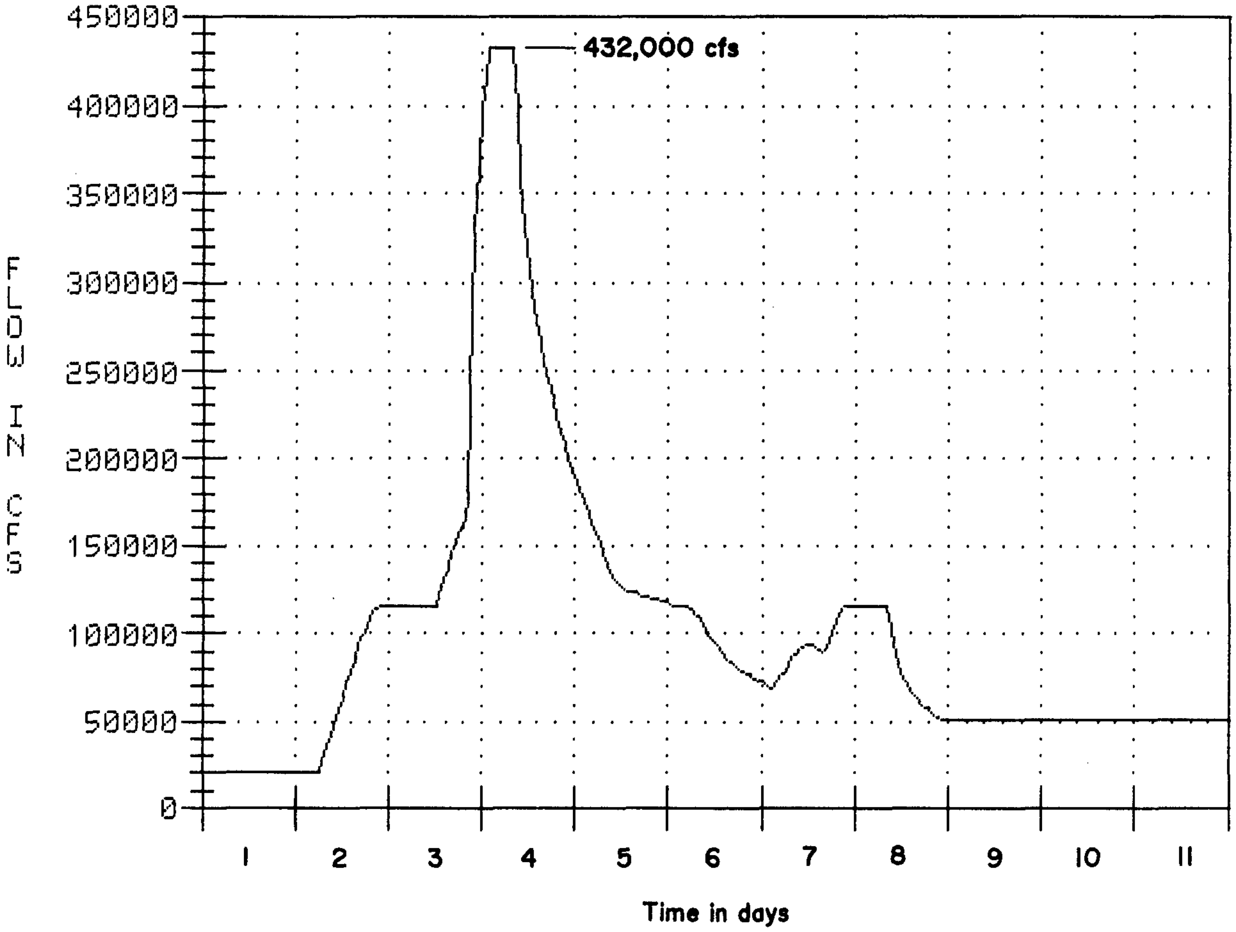
AMERICAN RIVER AND SACRAMENTO
METRO INVESTIGATIONS, CALIFORNIA

200-YR. COMPUTED HYDROGRAPH

FEATHER RIVER BELOW BEAR R.

CORPS OF ENGINEERS, SACRAMENTO, CALIFORNIA

Prepared: J.H.
Drawn: C.A.P.
Date: JANUARY 1990



AMERICAN RIVER AND SACRAMENTO
METRO INVESTIGATIONS, CALIFORNIA

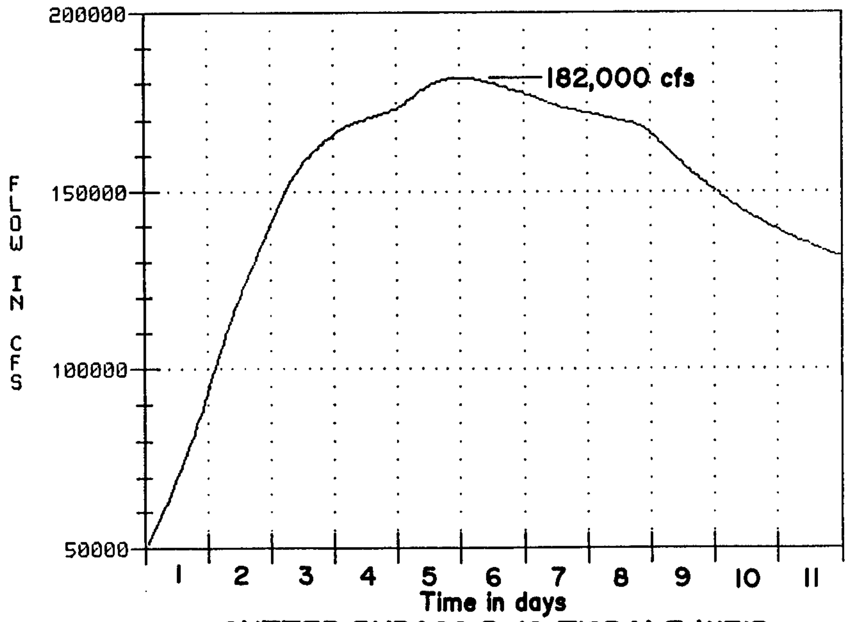
200-YR. COMPUTED HYDROGRAPH PREPROJECT

AMERICAN RIVER @ FAIR OAKS

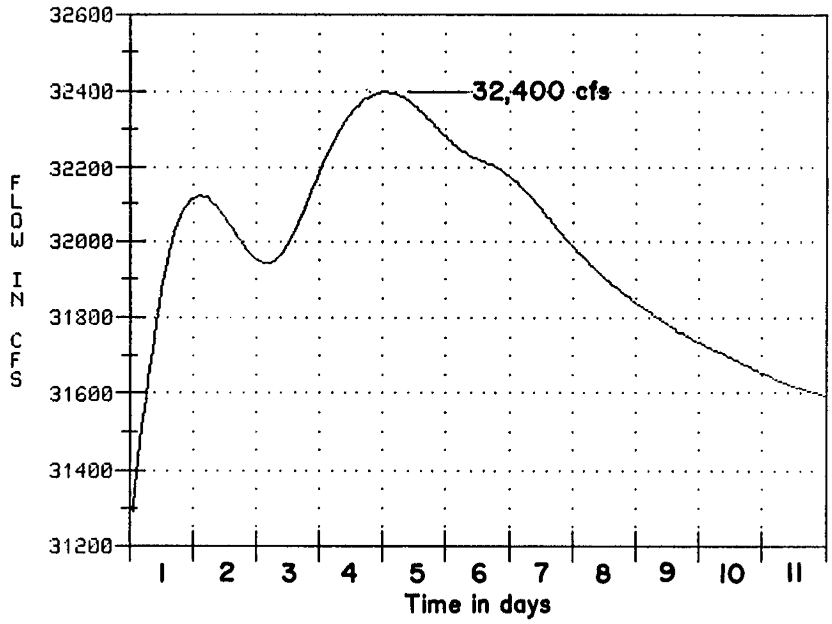
CORPS OF ENGINEERS. SACRAMENTO. CALIFORNIA

Prepared: J.H.
Drawn: C.A.P.

Date: JANUARY 1990



SUTTER BYPASS D/S TISDALE WEIR



SACRAMENTO RIVER @ WILKINS SL.

AMERICAN RIVER AND SACRAMENTO
METRO INVESTIGATIONS, CALIFORNIA

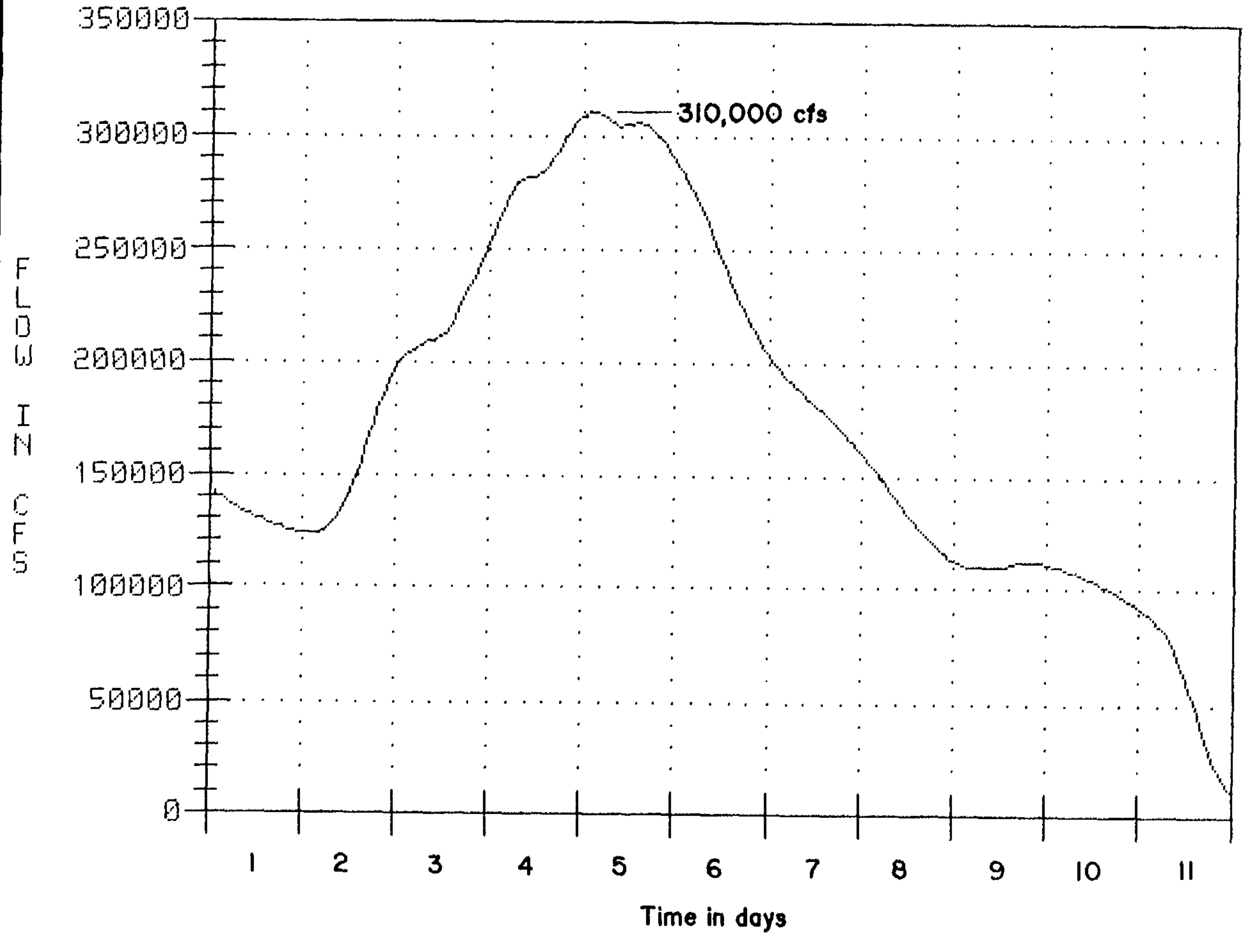
400-YR. COMPUTED HYDROGRAPH

CORPS OF ENGINEERS, SACRAMENTO, CALIFORNIA

Prepared: J.H.
Drawn: C.A.P.

Date: JANUARY 1990

SHEET 1 OF 3 CHART 35



AMERICAN RIVER AND SACRAMENTO
METRO INVESTIGATIONS, CALIFORNIA

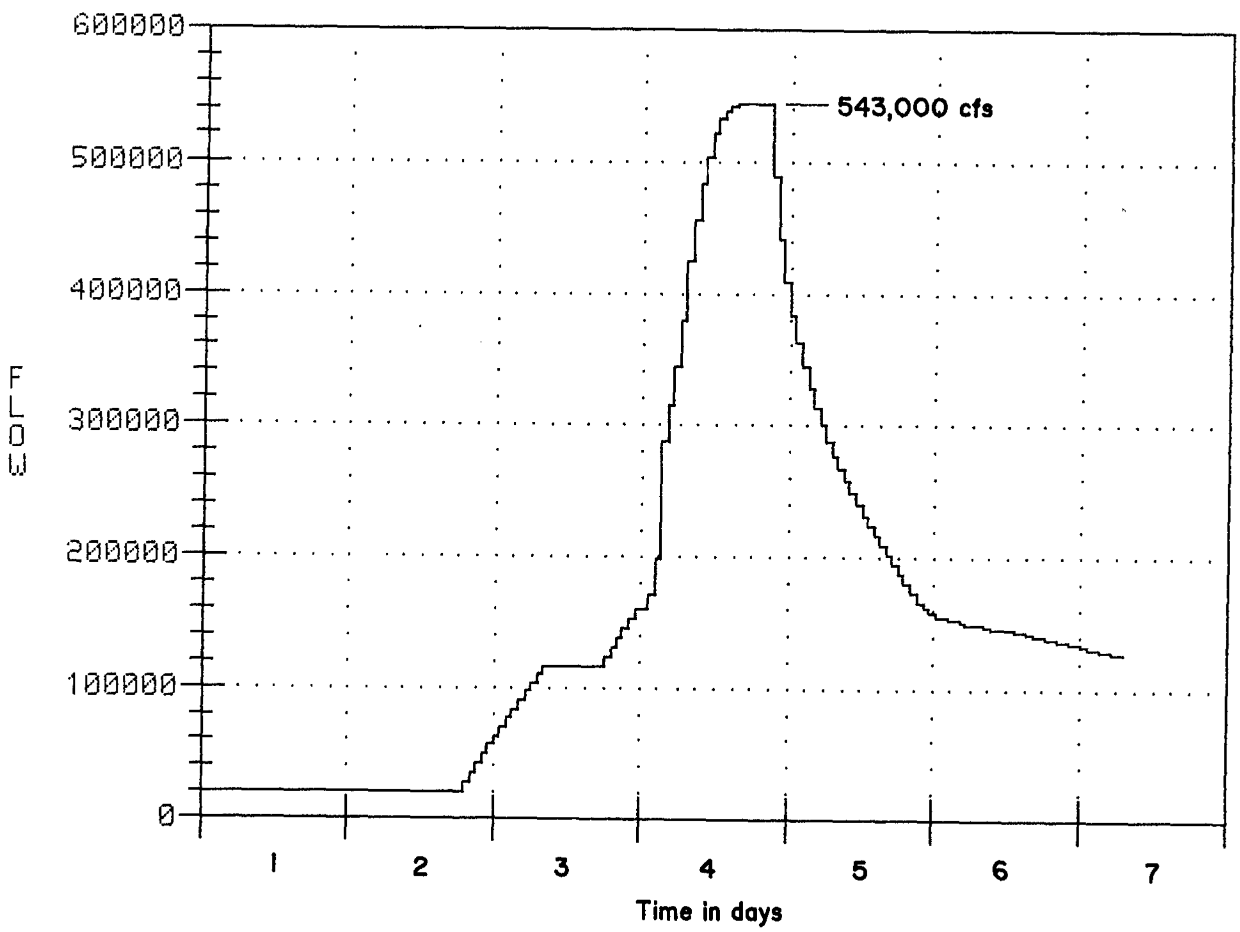
400-YR. COMPUTED HYDROGRAPH

FEATHER RIVER BELOW BEAR R.

CORPS OF ENGINEERS, SACRAMENTO, CALIFORNIA

Prepared: J.H.
Drawn: C.A.P.
Date: JANUARY 1990

SHEET 2 OF 3 CHART 35



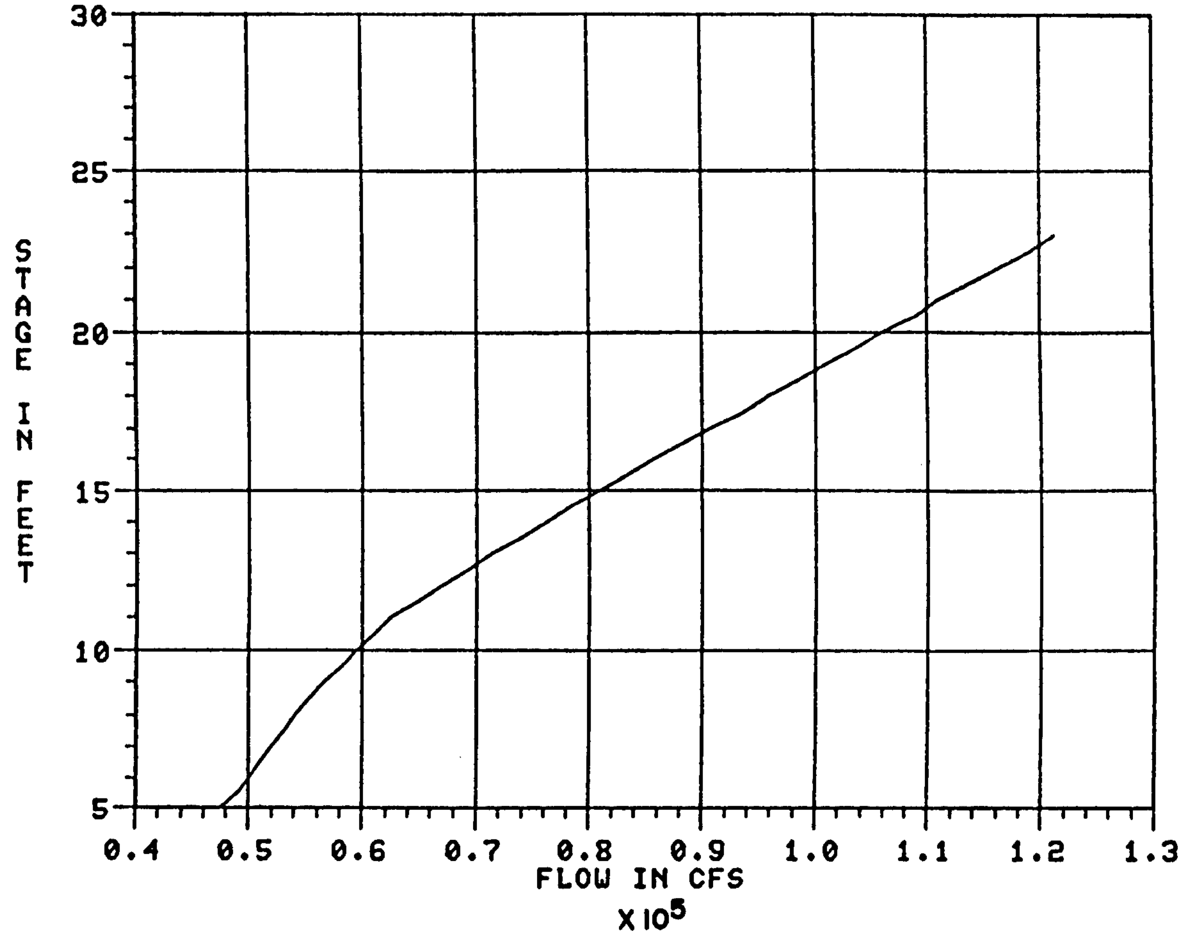
AMERICAN RIVER AND SACRAMENTO
METRO INVESTIGATIONS, CALIFORNIA

400-YR. COMPUTED HYDROGRAPH PREPROJECT

AMERICAN RIVER @ FAIR OAKS

CORPS OF ENGINEERS. SACRAMENTO. CALIFORNIA

Prepared: J.H.
Drawn: C.A.P.
Date: JANUARY 1990



AMERICAN RIVER AND SACRAMENTO
METRO INVESTIGATIONS, CALIFORNIA

RATING CURVE

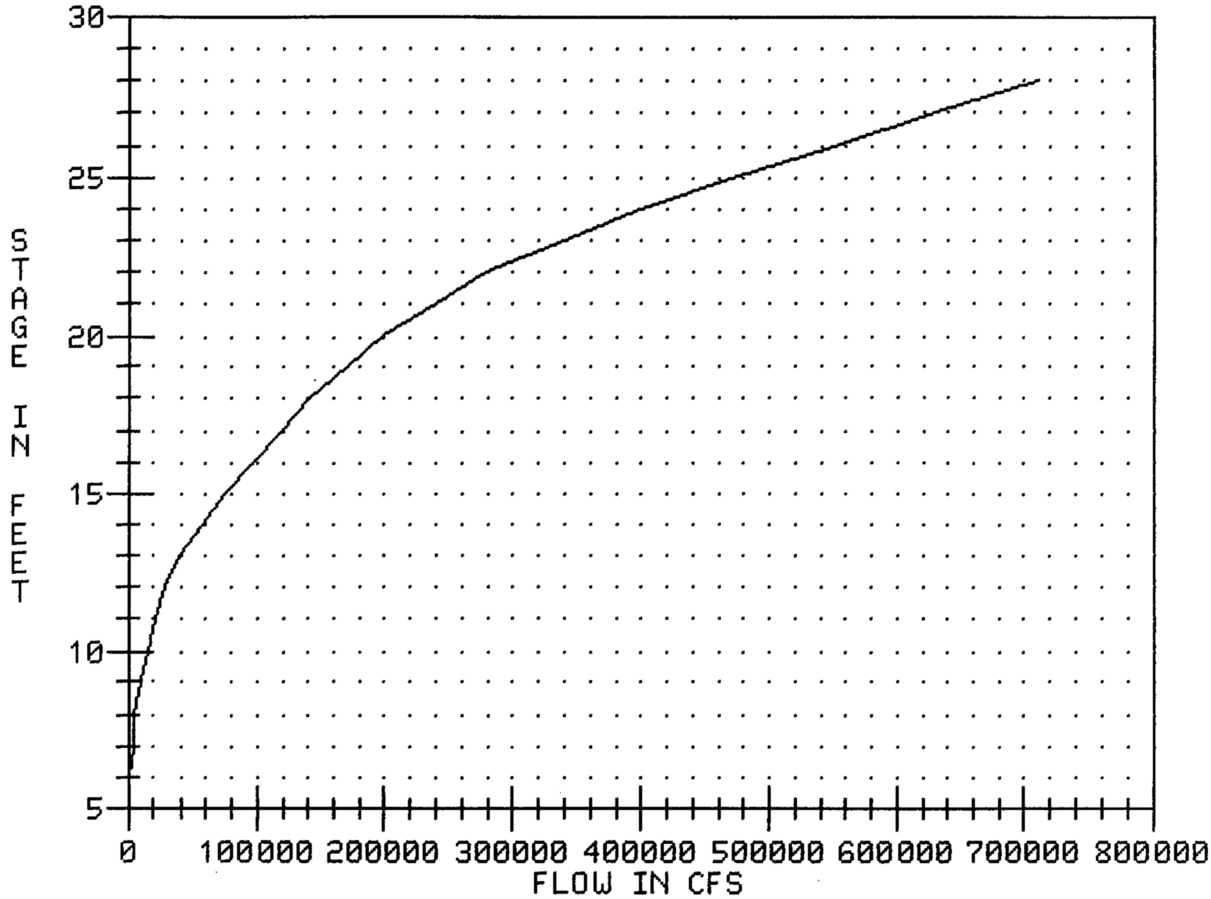
SACRAMENTO RIVER @ SNODGRASS SL.

CORPS OF ENGINEERS. SACRAMENTO. CALIFORNIA

Prepared: J.H.
Drawn: C.A.P.

Date: JANUARY 1990

CHART 36



AMERICAN RIVER AND SACRAMENTO
METRO INVESTIGATIONS, CALIFORNIA

RATING CURVE

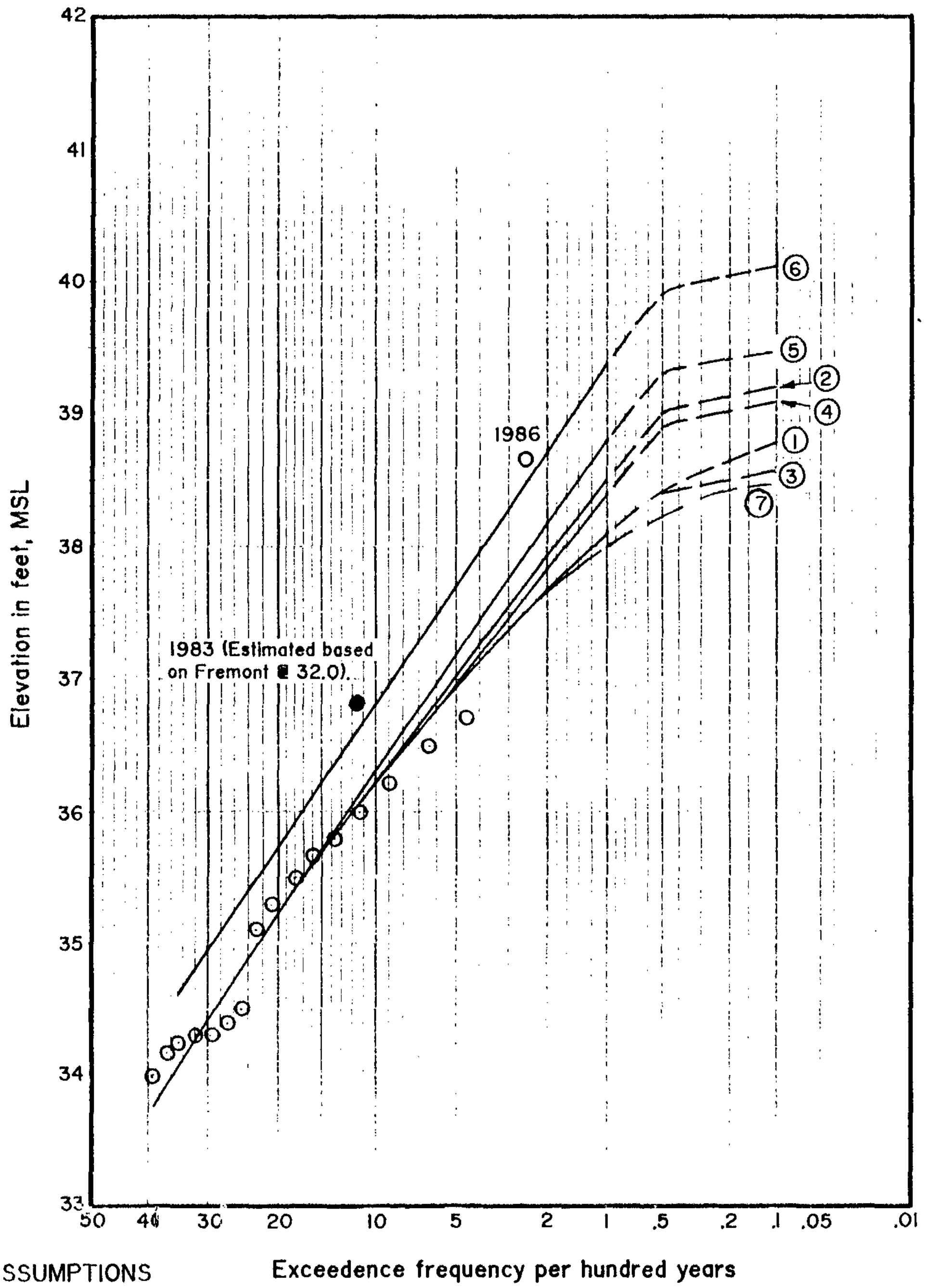
YOLO BYPASS AT LISBON

CORPS OF ENGINEERS. SACRAMENTO. CALIFORNIA

Prepared: J.H.
Drawn: C.A.P.

Date: JANUARY 1990

CHART 37



CURVE	ASSUMPTIONS USED
1	2, 4, 5, 8, 9
2	2, 5, 8, 9
3	2, 4, 6, 8, 9
4	2, 6, 8, 9
5	1, 4, 5, 8, 9
6	1, 5, 8, 9
7	3, 5, 7, 8, 9

ASSUMPTIONS

1. Fremont Weir @ 32.0
2. Fremont Weir @31.0
3. Fremont Weir @ 30.5
4. Area C Failure
5. American River Failures
6. American River @ 115,000 cfs
7. South Levee Natomas Cross Canal Failure
8. No Failure on Sac R. below American River
9. No Failure in Yolo Bypass

AMERICAN RIVER AND SACRAMENTO METRO INVESTIGATIONS, CALIFORNIA

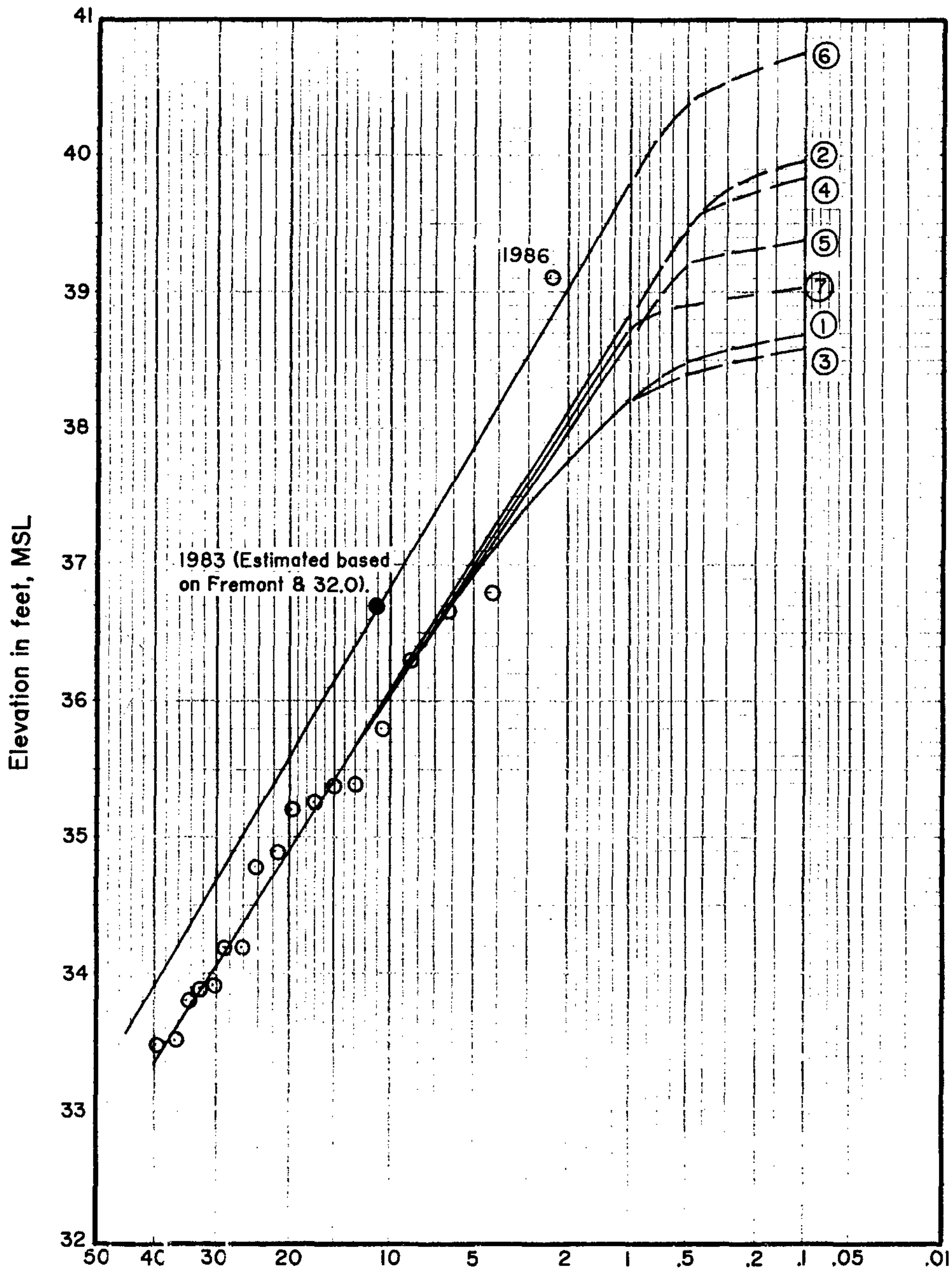
STAGE-FREQUENCY CURVES

SACRAMENTO RIVER @ FREMONT WEIR, WEST END

CORPS OF ENGINEERS. SACRAMENTO. CALIFORNIA

Prepared: J.H.
Drawn. C.A.P.
Date: **JANUARY 1990**

CHART 38



CURVE	ASSUMPTIONS USED
1	2, 4, 5, 8, 9
2	2, 5, 8, 9
3	2, 4, 6, 8, 9
4	2, 6, 8, 9
5	1, 4, 5, 8, 9
6	1, 5, 8, 9
7	3, 5, 7, 8, 9

ASSUMPTIONS

1. Fremont Weir @ 32.0
2. Fremont Weir @31.0
3. Fremont Weir @ 30.5
4. Area C Failure
5. American River Failures
6. American River @ 115,000 cfs
7. South Levee Natomas Cross Canal Failure
8. No Failure on Sac R. below American River
9. No Failure in Yolo Bypass

AMERICAN RIVER AND SACRAMENTO
METRO INVESTIGATIONS, CALIFORNIA

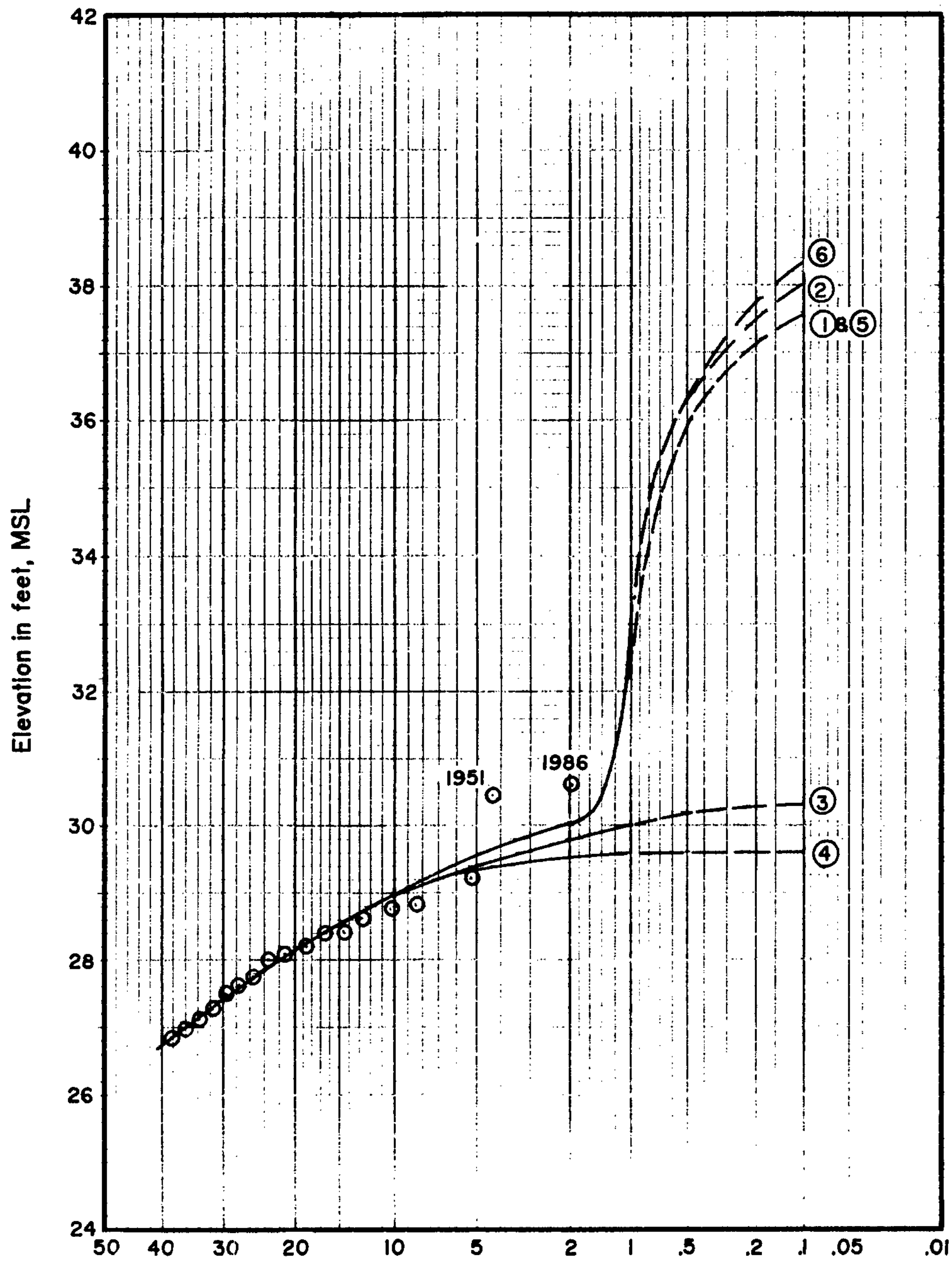
STAGE-FREQUENCY CURVES

SACRAMENTO RIVER @ VERONA

CORPS OF ENGINEERS. SACRAMENTO. CALIFORNIA

Prepared: J.H.
Drawn: C.A.P.
Date: JANUARY 1990

CHART 39



Exceedence frequency per hundred years

CURVE	ASSUMPTIONS USED
1	2, 4, 5, 8, 9
2	2, 5, 8, 9
3	2, 4, 6, 8, 9
4	2, 6, 8, 9
5	1, 4, 5, 8, 9
6	1, 5, 8, 9

ASSUMPTIONS

1. Fremont Weir @ 32.0
2. Fremont Weir @31.0
3. Fremont Weir @ 30.5
4. Area C Failure
5. American River Failures
6. American River @ 115,000 cfs
7. South Levee Natomas Cross Canal Failure
8. No Failure on Sac R. below American River
9. No Failure in Yolo Bypass

AMERICAN RIVER AND SACRAMENTO
METRO INVESTIGATIONS, CALIFORNIA

STAGE-FREQUENCY CURVES

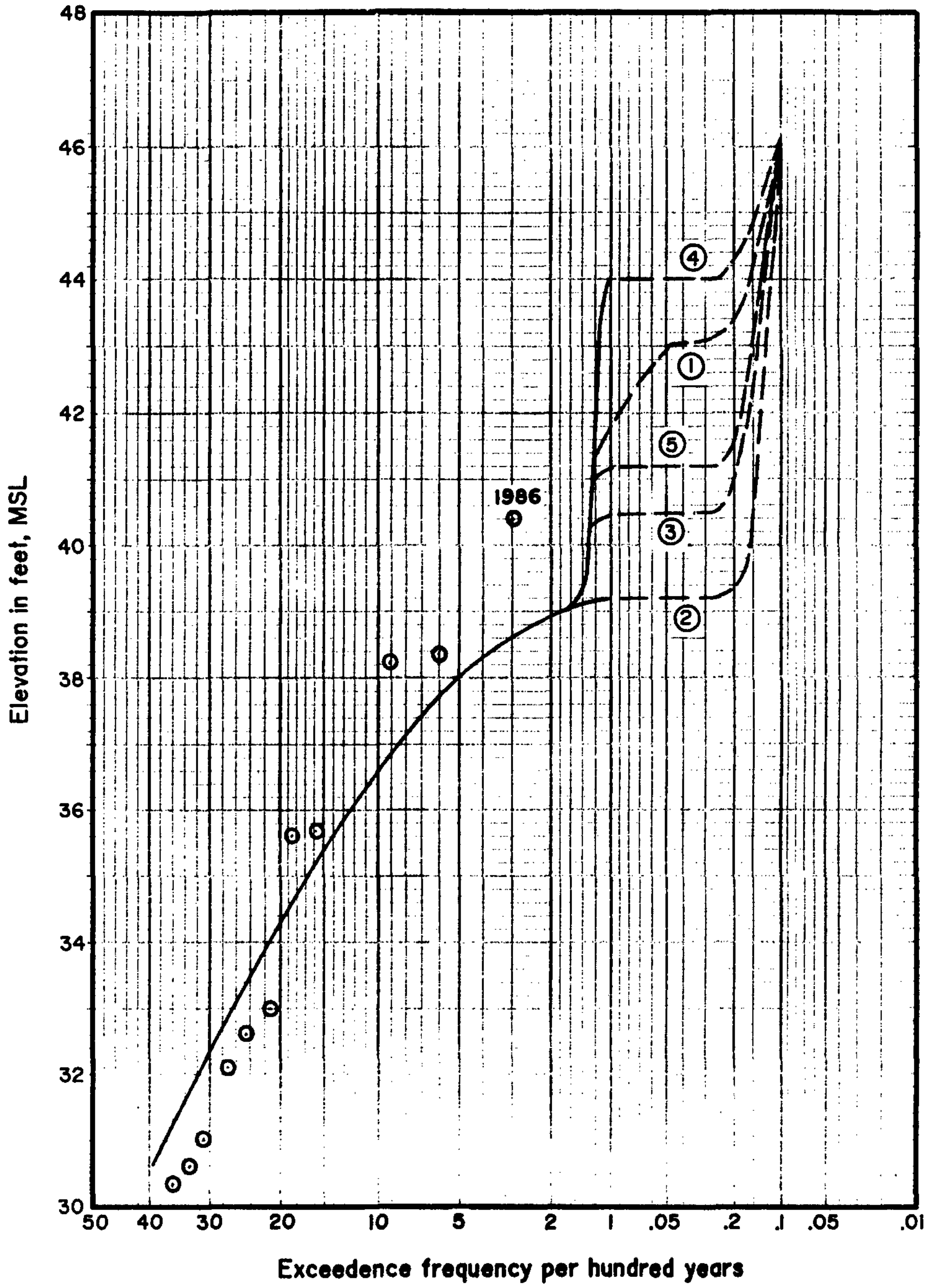
SACRAMENTO RIVER @ I-STREET

CORPS OF ENGINEERS. SACRAMENTO. CALIFORNIA

Prepared: J.H.
Drawn: C.A.P.

Date: JANUARY 1990

CHART 40



① Freeboard Failures
② 115,000 in American
③ 130,000 in American
④ 180,000 in American (No Failures)
⑤ 180,000 in American (Freeboard Failures)

AMERICAN RIVER AND SACRAMENTO
METRO INVESTIGATIONS, CALIFORNIA

STAGE-FREQUENCY CURVES

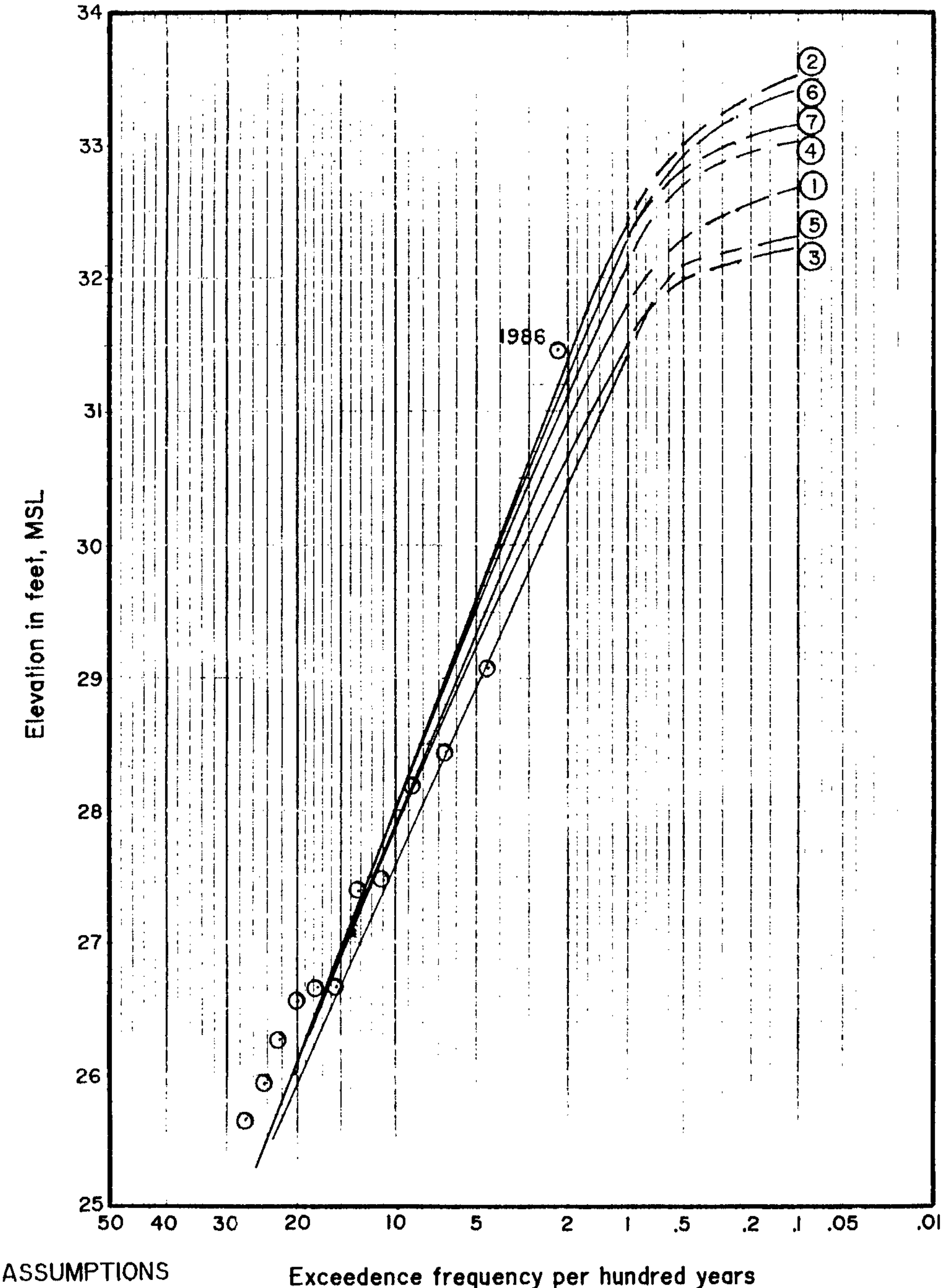
AMERICAN RIVER @ H-STREET

CORPS OF ENGINEERS. SACRAMENTO. CALIFORNIA

Prepared : J.H.
Drawn : C.A.P.

Date : JANUARY 1990

CHART 41



CURVE	ASSUMPTIONS USED
1	2, 4, 5, 8, 9
2	2, 5, 8, 9
3	2, 4, 6, 8, 9
4	2, 6, 8, 9
5	1, 4, 5, 8, 9
6	1, 5, 8, 9
7	3, 5, 7, 8, 9

ASSUMPTIONS

1. Fremont Weir @ 32.0
2. Fremont Weir @31.0
3. Fremont Weir @ 30.5
4. Area C Failure
5. American River Failures
6. American River @ 115,000 cfs
7. South Levee Natomas Cross Canal Failure
8. No Failure on Sac R. below American River
9. No Failure in Yolo Bypass

AMERICAN RIVER AND SACRAMENTO
METRO INVESTIGATIONS, CALIFORNIA

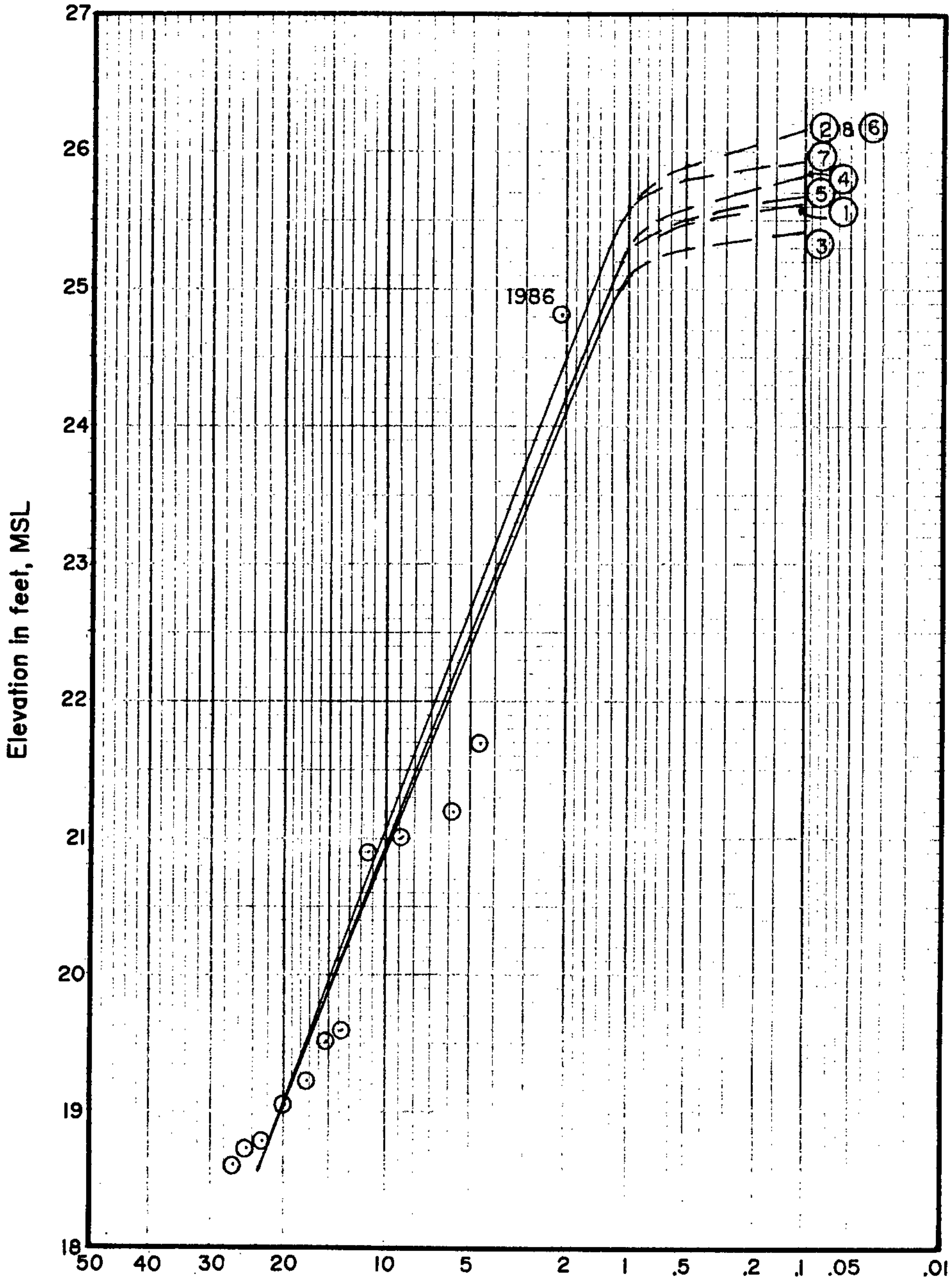
STAGE-FREQUENCY CURVES

YOLO BYPASS @ WOODLAND

CORPS OF ENGINEERS, SACRAMENTO, CALIFORNIA

Prepared: J.H.
Drawn: C.A.P.
Date: JANUARY 1990

CHART 42



CURVE	ASSUMPTIONS USED
1	2, 4, 5, 8, 9
2	2, 5, 8, 9
3	2, 4, 6, 8, 9
4	2, 6, 8, 9
5	1, 4, 5, 8, 9
6	1, 5, 8, 9
7	3, 5, 7, 8, 9

ASSUMPTIONS

1. Fremont Weir @ 32.0
2. Fremont Weir @31.0
3. Fremont Weir @ 30.5
4. Area C Failure
5. American River Failures
6. American River @ 115,000 cfs
7. South Levee Natomas Cross Canal Failure
8. No Failure on Sac R. below American River
9. No Failure in Yolo Bypass

AMERICAN RIVER AND SACRAMENTO
METRO INVESTIGATIONS, CALIFORNIA

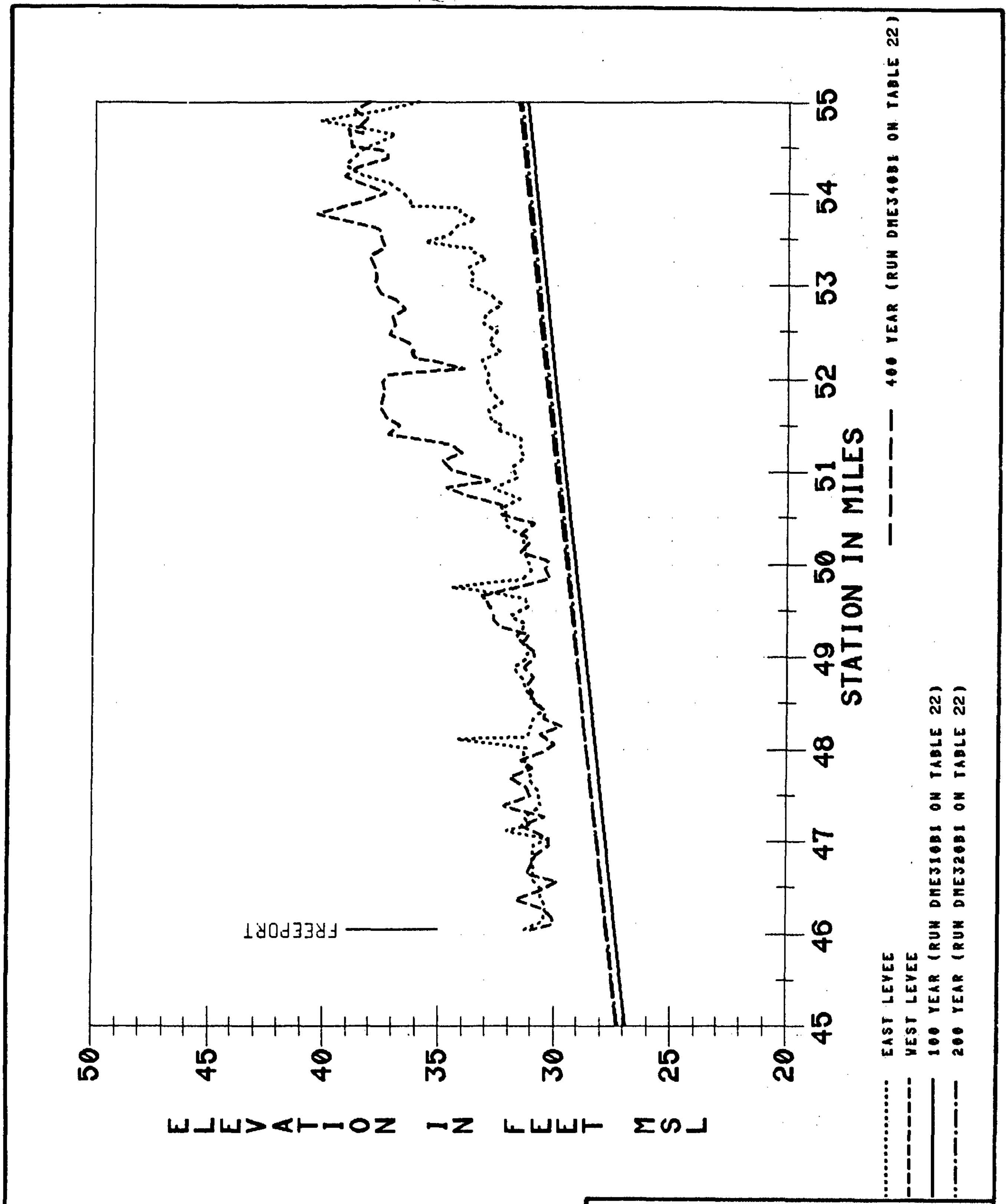
STAGE-FREQUENCY CURVES

YOLO BYPASS @ LISBON

CORPS OF ENGINEERS. SACRAMENTO. CALIFORNIA

Prepared : J.H.
Drawn : C.A.P.
Date : JANUARY 1990

CHART 43



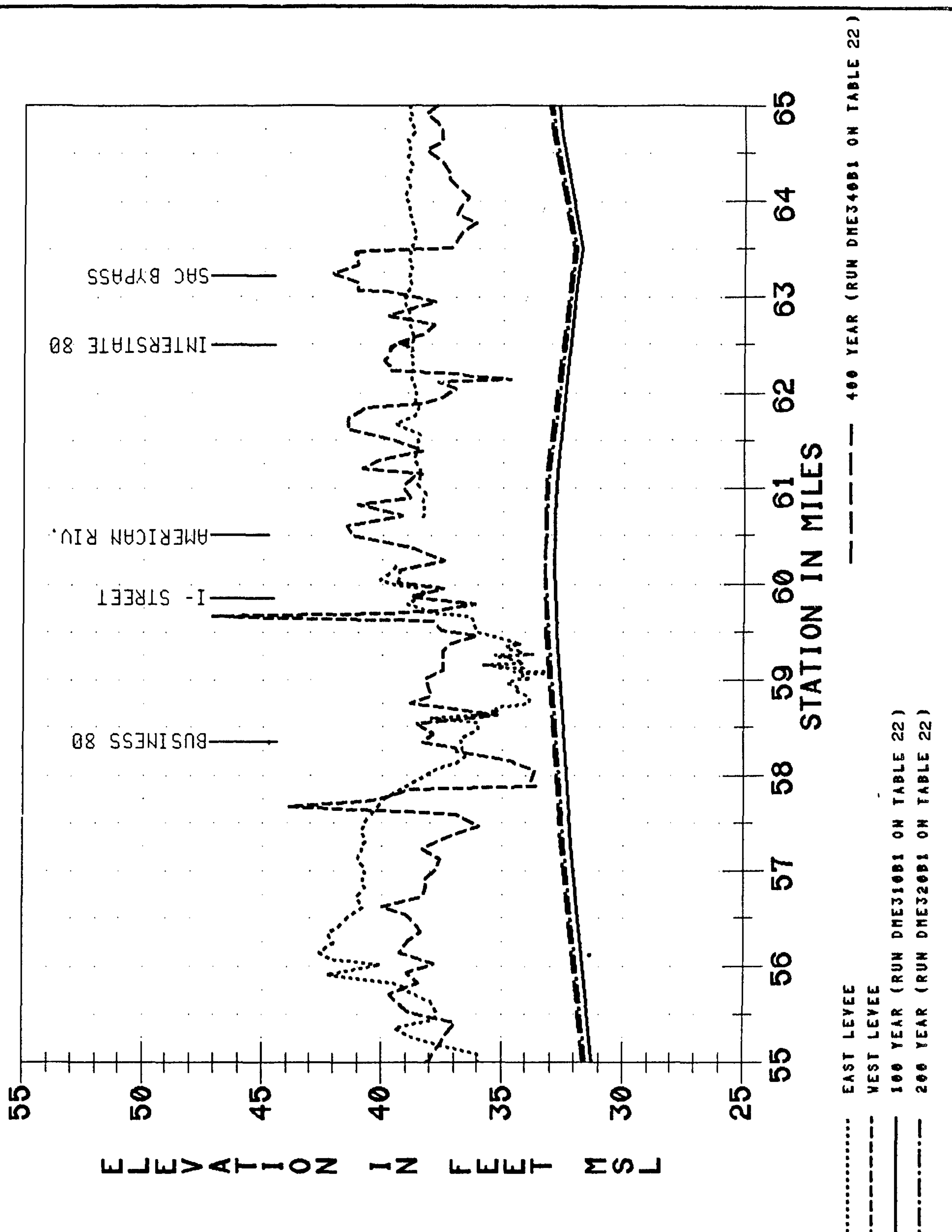
AMERICAN RIVER AND SACRAMENTO
METRO INVESTIGATIONS, CALIFORNIA

SACRAMENTO RIVER
NO AREA C FAILURES

CORPS OF ENGINEERS. SACRAMENTO. CALIFORNIA

Prepared : J.H.
Drawn : J.H.
Date : JANUARY 1990

SHEET 1 OF 4 CHART 44



AMERICAN RIVER AND SACRAMENTO
METRO INVESTIGATIONS, CALIFORNIA

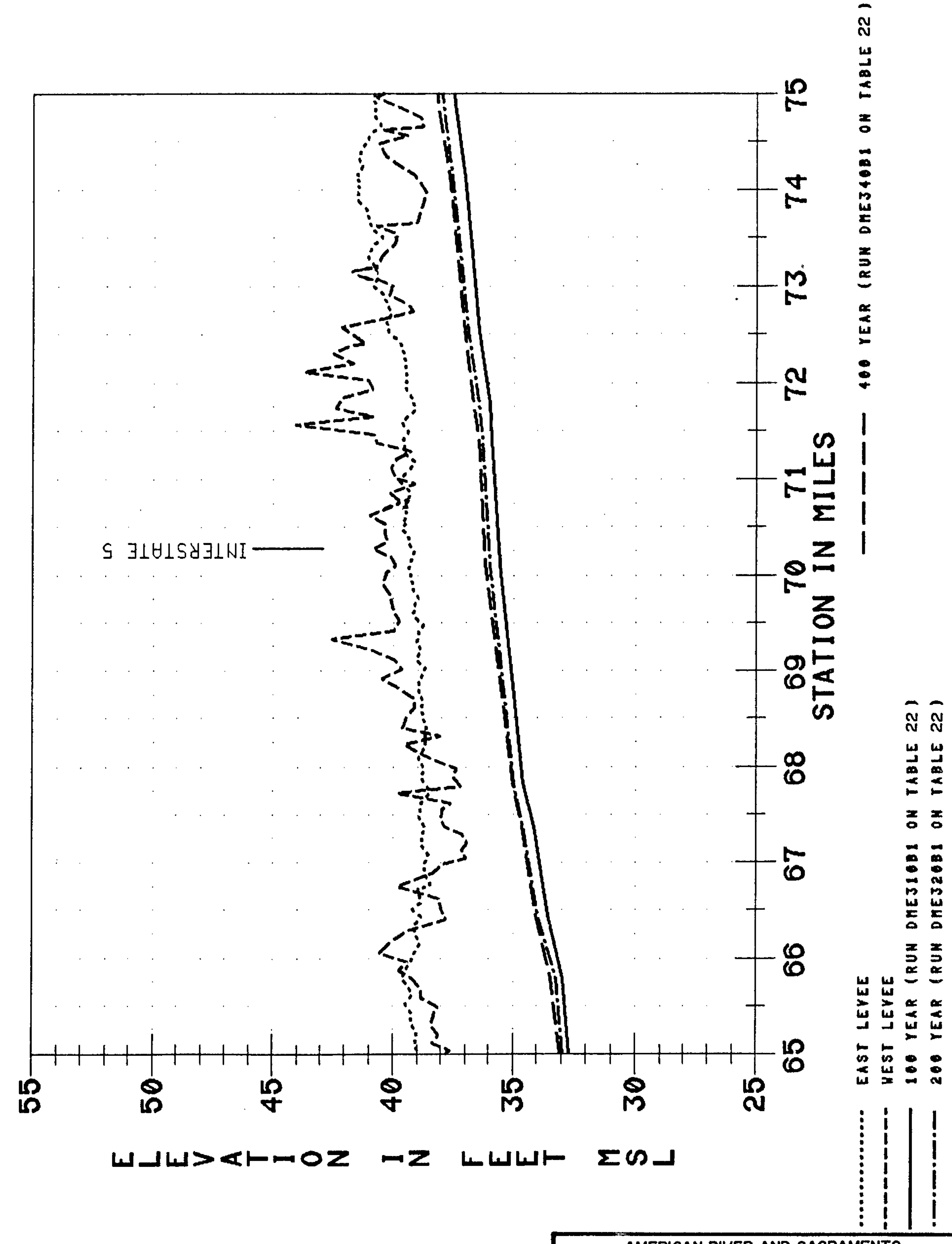
SACRAMENTO RIVER
NO AREA C FAILURES

CORPS OF ENGINEERS. SACRAMENTO. CALIFORNIA

Prepared: J.H.
Drawn: J.H.

Date: JANUARY 1990

SHEET 2 OF 4 CHART 44



AMERICAN RIVER AND SACRAMENTO
METRO INVESTIGATIONS, CALIFORNIA

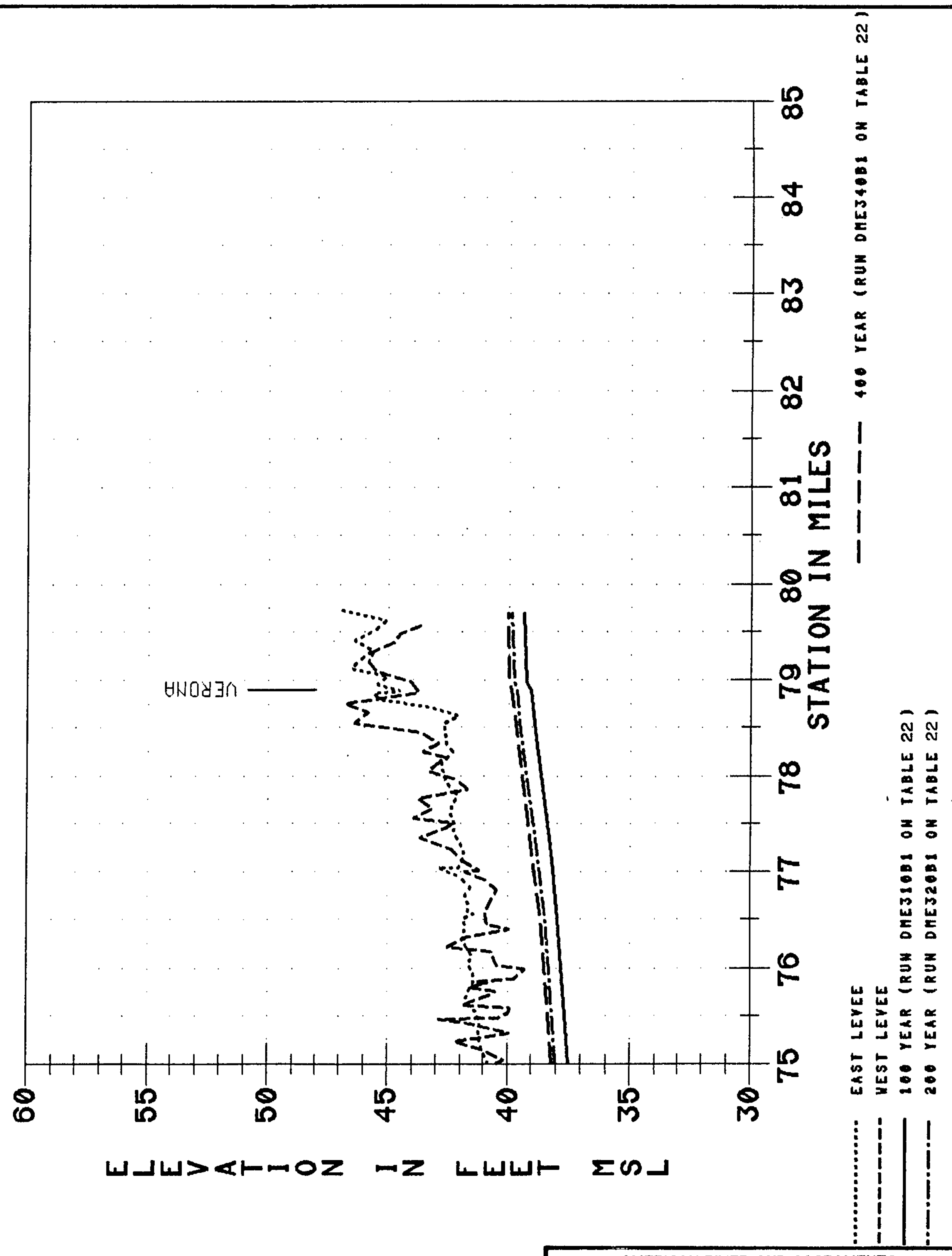
SACRAMENTO RIVER
NO AREA C FAILURES

CORPS OF ENGINEERS, SACRAMENTO, CALIFORNIA

Prepared: J.H.
Drawn: J.H.

Date: JANUARY 1990

SHEET 3 OF 4 CHART 44

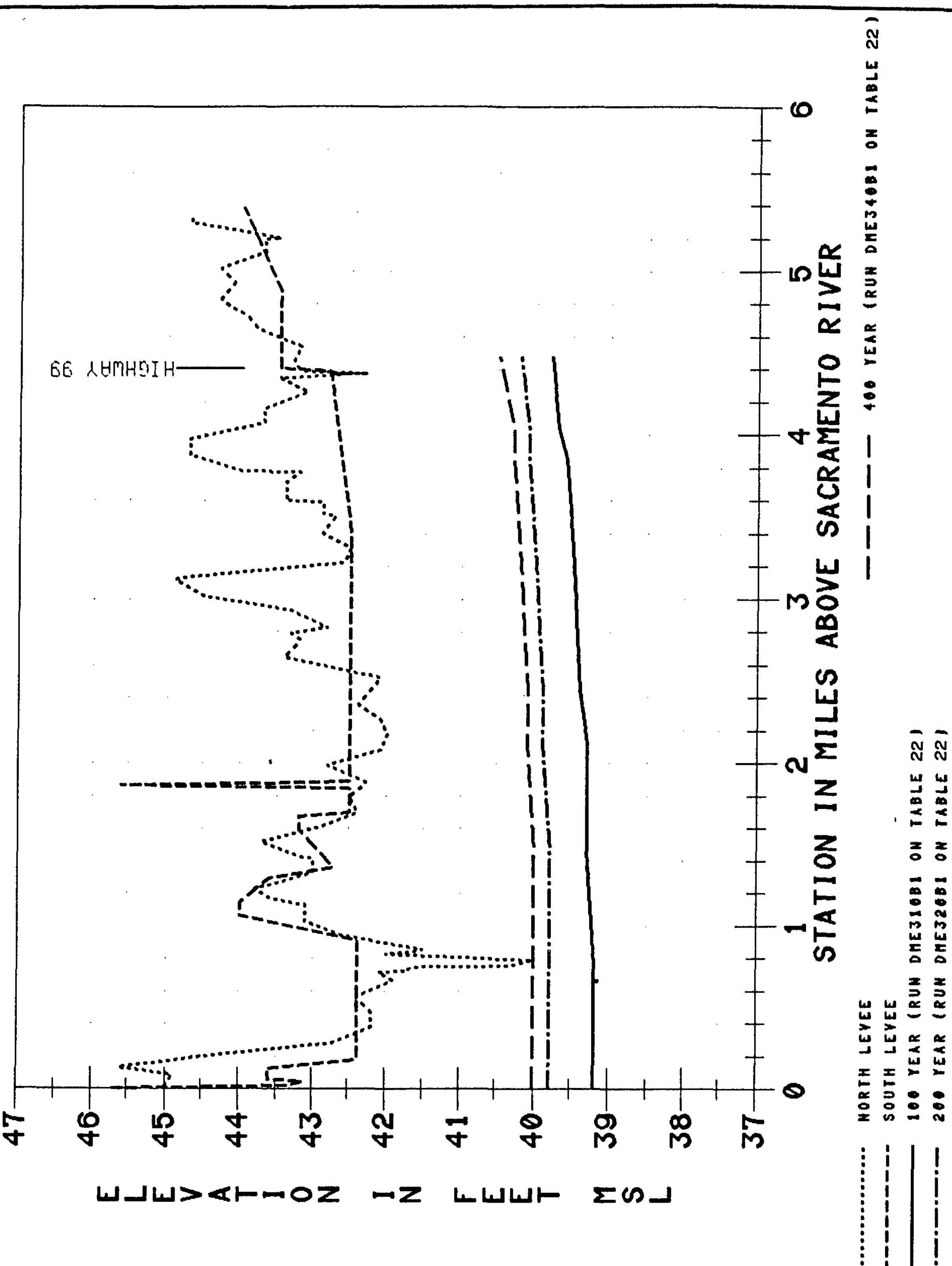


AMERICAN RIVER AND SACRAMENTO
METRO INVESTIGATIONS, CALIFORNIA

SACRAMENTO RIVER
NO AREA C FAILURES

CORPS OF ENGINEERS, SACRAMENTO, CALIFORNIA

Prepared: J.H.
Drawn: J.H.
Date: JANUARY 1990



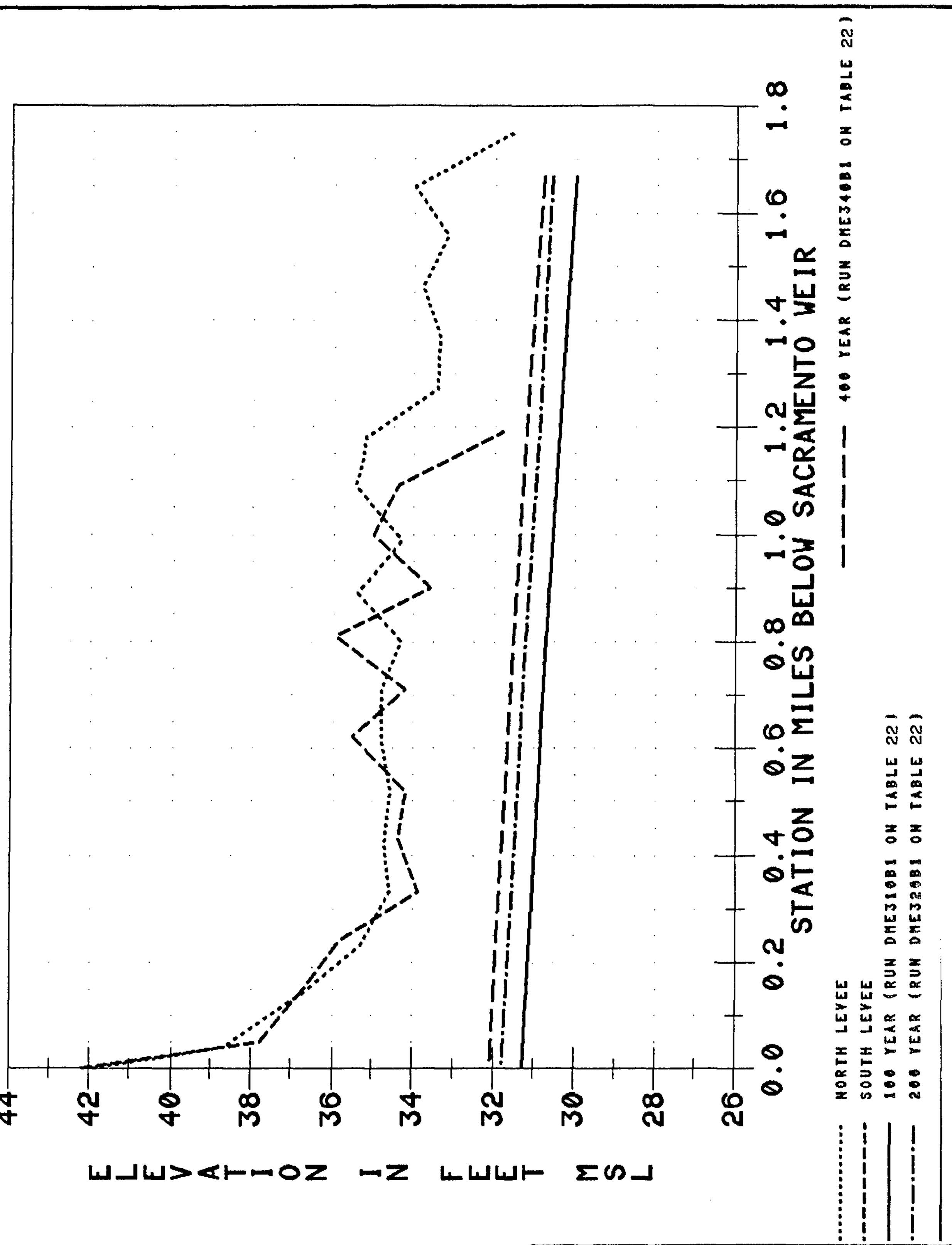
AMERICAN RIVER AND SACRAMENTO
METRO INVESTIGATIONS, CALIFORNIA

NATOMAS CROSS CANAL
NO AREA C FAILURES

CORPS OF ENGINEERS. SACRAMENTO. CALIFORNIA

Prepared: J.H.
Drawn: J.H.
Date: JANUARY 1990

CHART 45



AMERICAN RIVER AND SACRAMENTO
METRO INVESTIGATIONS, CALIFORNIA

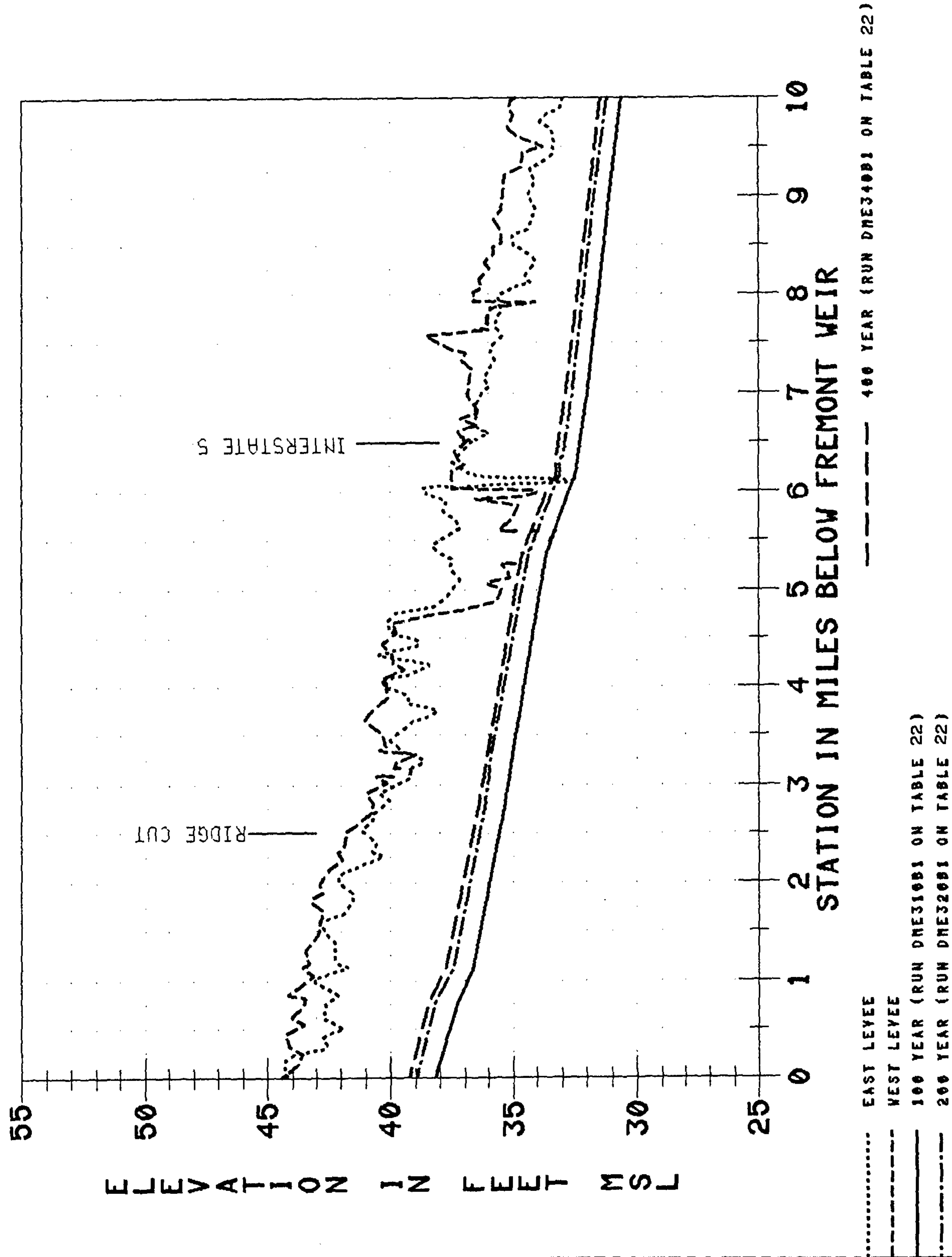
SACRAMENTO BYPASS
NO AREA C FAILURES

CORPS OF ENGINEERS. SACRAMENTO. CALIFORNIA

Prepared: J.H.
Drawn: J.H.

Date: JANUARY 1990

CHART 46



AMERICAN RIVER AND SACRAMENTO
METRO INVESTIGATIONS, CALIFORNIA

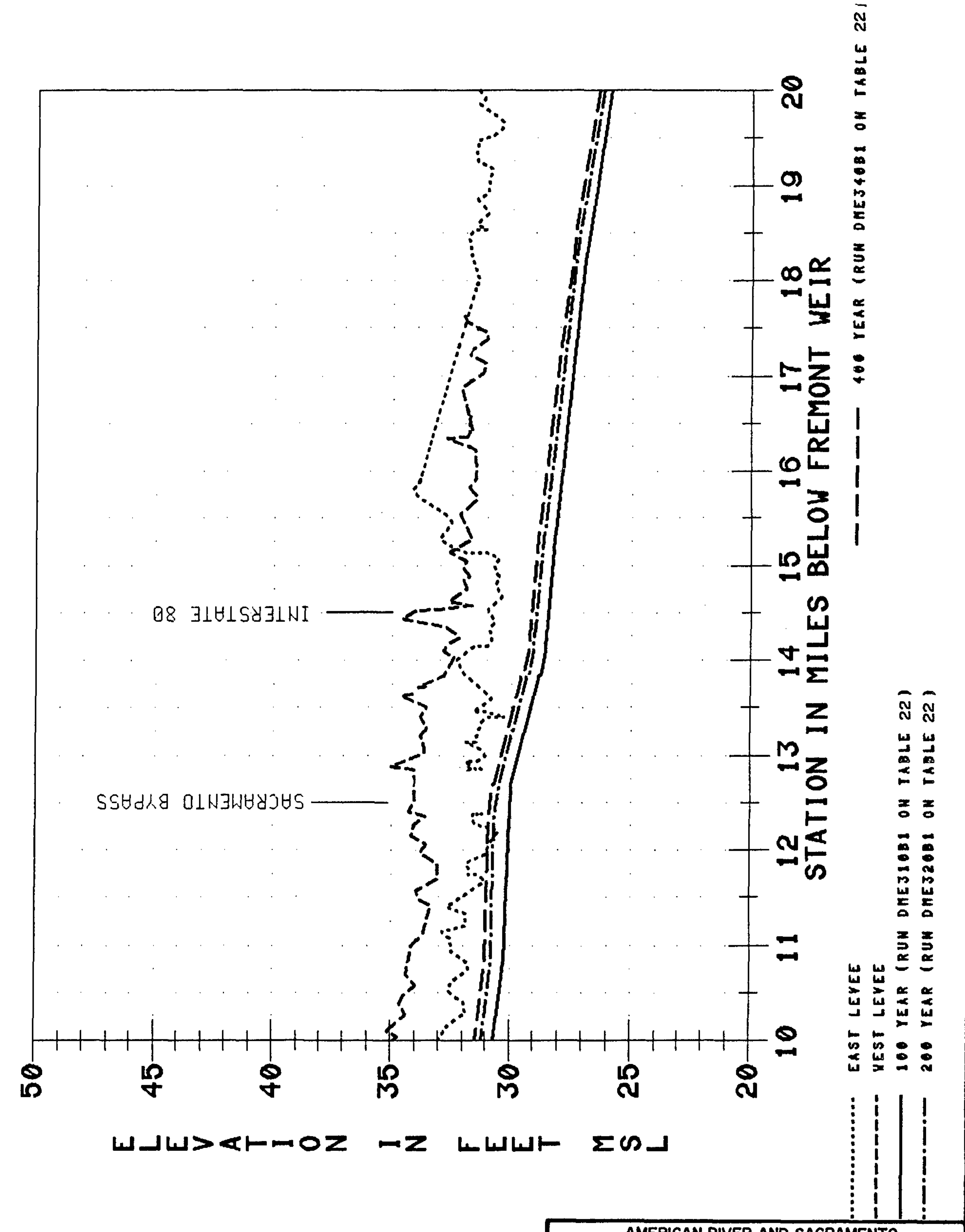
YOLO BYPASS
NO AREA C FAILURES

CORPS OF ENGINEERS, SACRAMENTO, CALIFORNIA

Prepared: J.H.
Drawn: J.H.

Date: JANUARY 1990

SHEET 1 OF 3 CHART 47



AMERICAN RIVER AND SACRAMENTO
METRO INVESTIGATIONS, CALIFORNIA

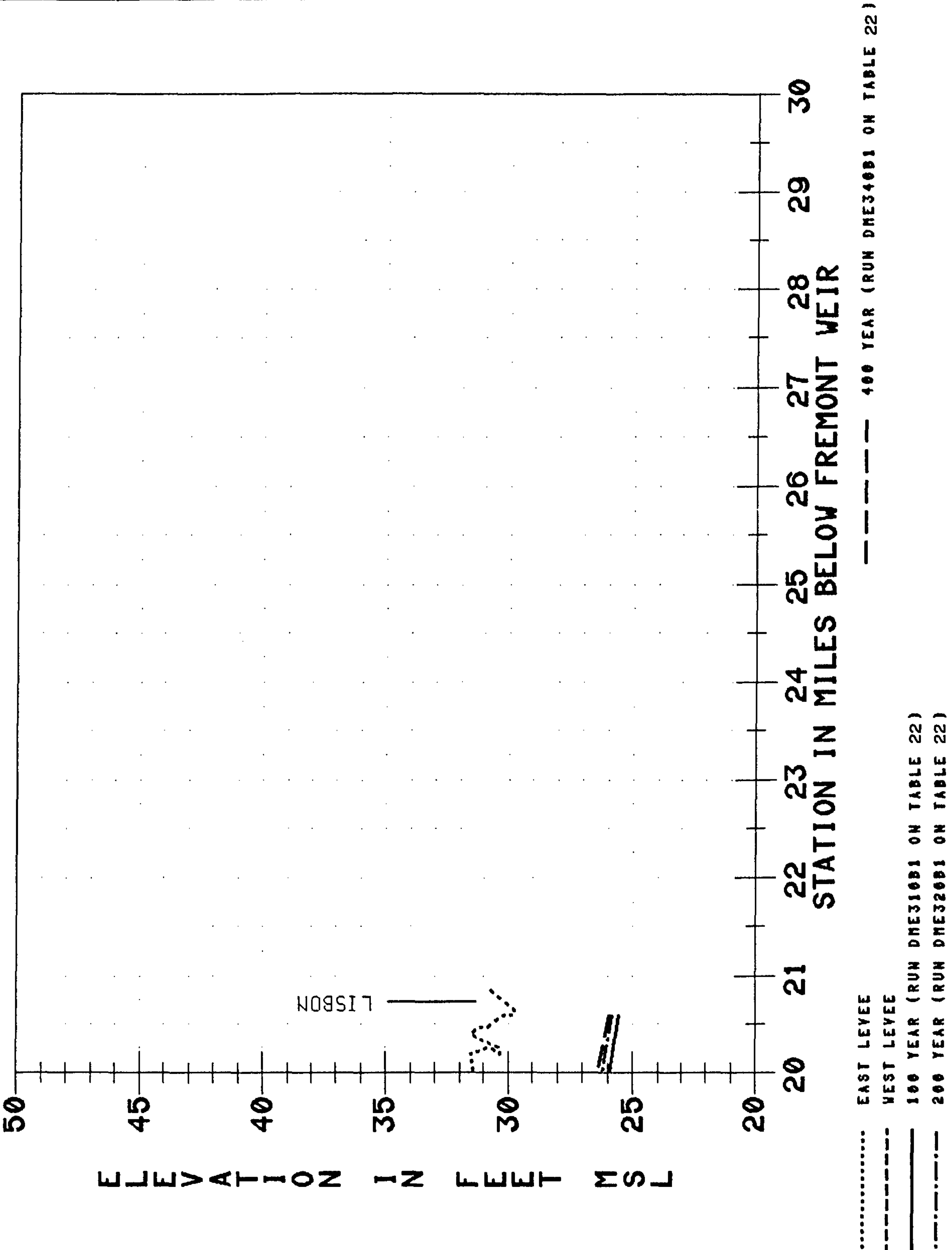
YOLO BYPASS
NO AREA C FAILURES

CORPS OF ENGINEERS, SACRAMENTO, CALIFORNIA

Prepared: J.H.
Drawn: J.H.

Date: JANUARY 1990

SHEET 2 OF 3 CHART 47



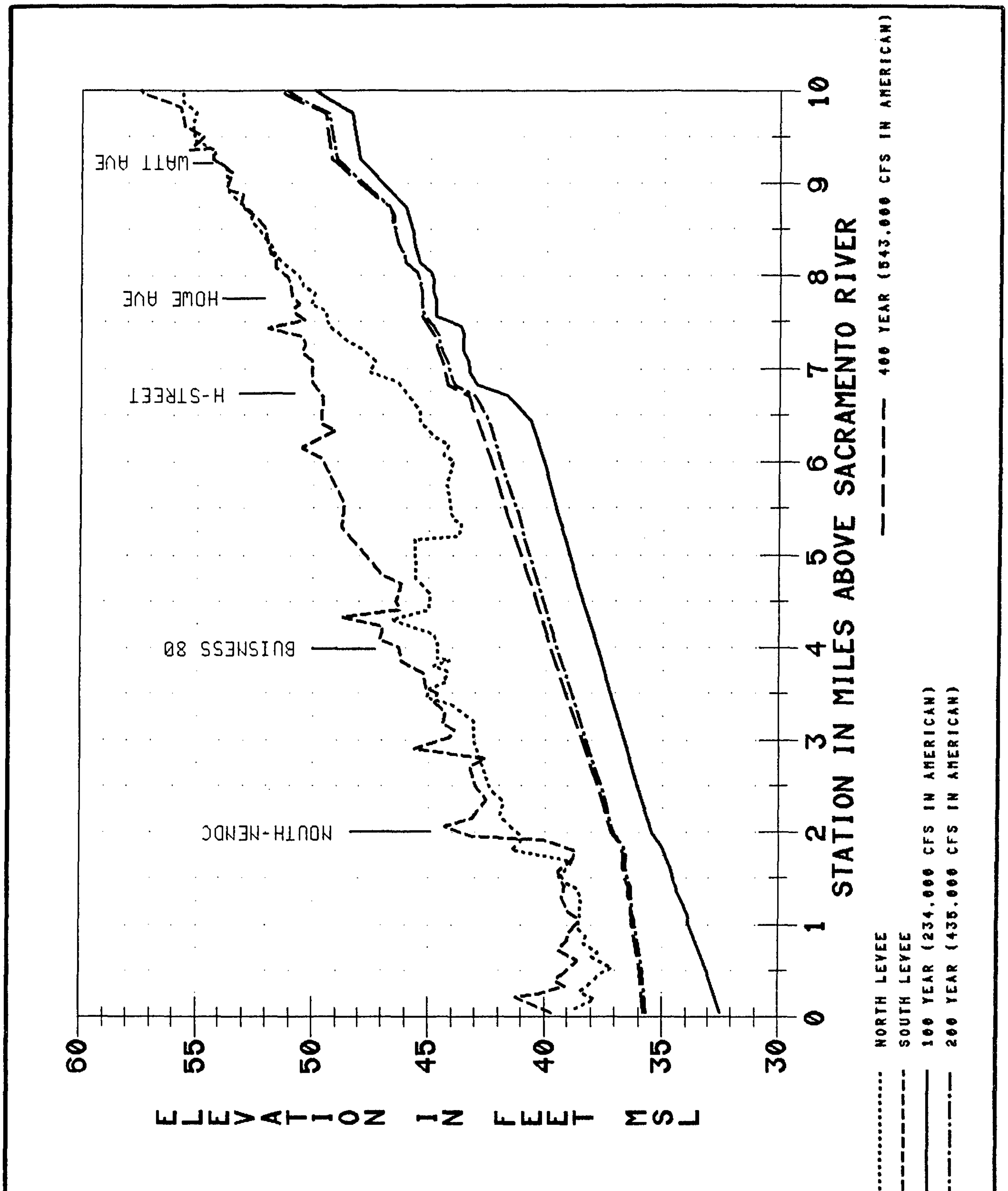
AMERICAN RIVER AND SACRAMENTO
METRO INVESTIGATIONS, CALIFORNIA

YOLO BYPASS
NO AREA C FAILURES

CORPS OF ENGINEERS. SACRAMENTO. CALIFORNIA

Prepared: J.H.
Drawn: J.H.
Date: JANUARY 1990

SHEET 3 OF 3 CHART 47



AMERICAN RIVER AND SACRAMENTO
METRO INVESTIGATIONS, CALIFORNIA

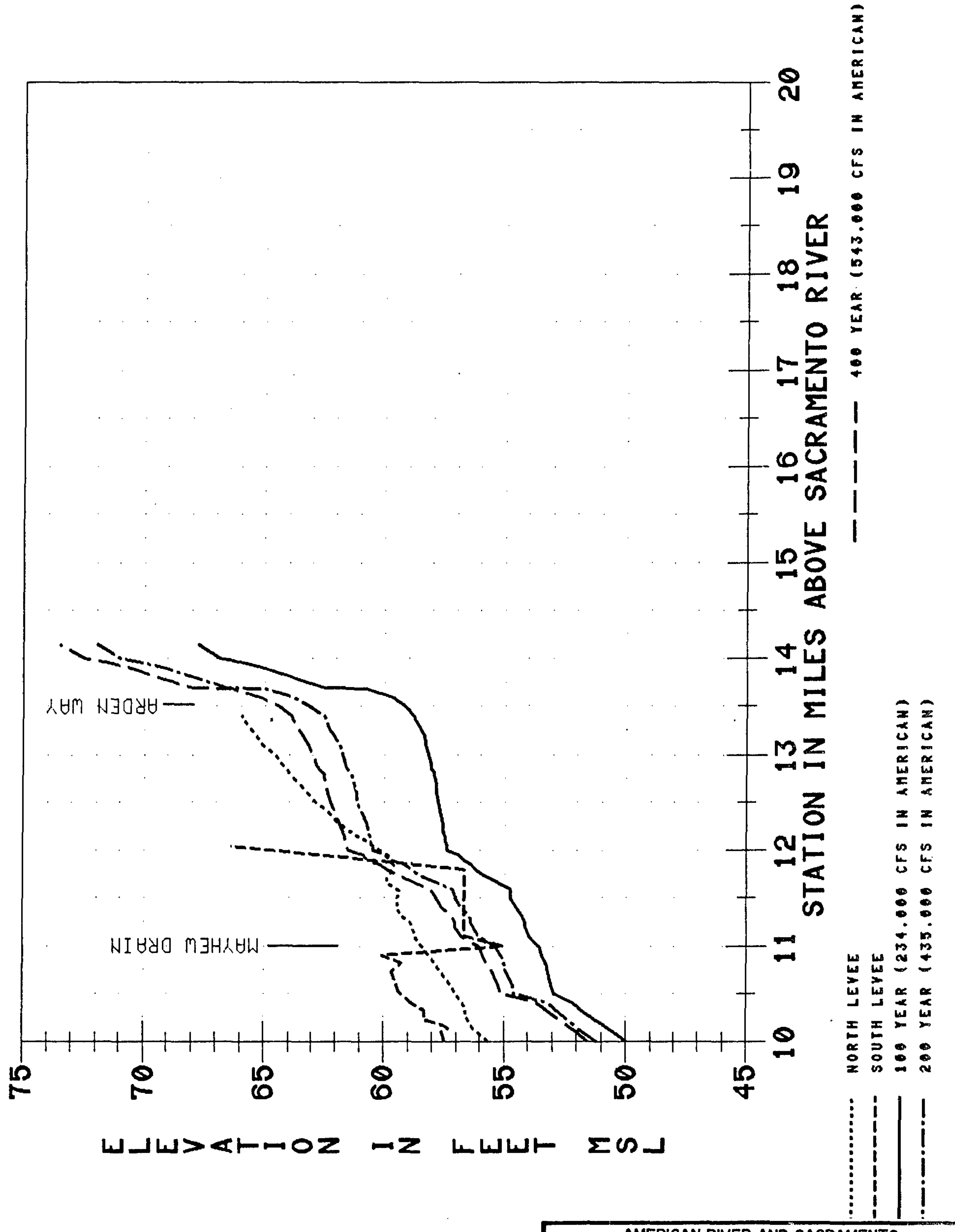
AMERICAN RIVER WITH FREEBOARD FAILURES

CORPS OF ENGINEERS. SACRAMENTO. CALIFORNIA

Prepared: J.H.
Drawn: J.H.

Date: JANUARY 1990

SHEET 1 OF 2 CHART 48



AMERICAN RIVER AND SACRAMENTO
METRO INVESTIGATIONS, CALIFORNIA

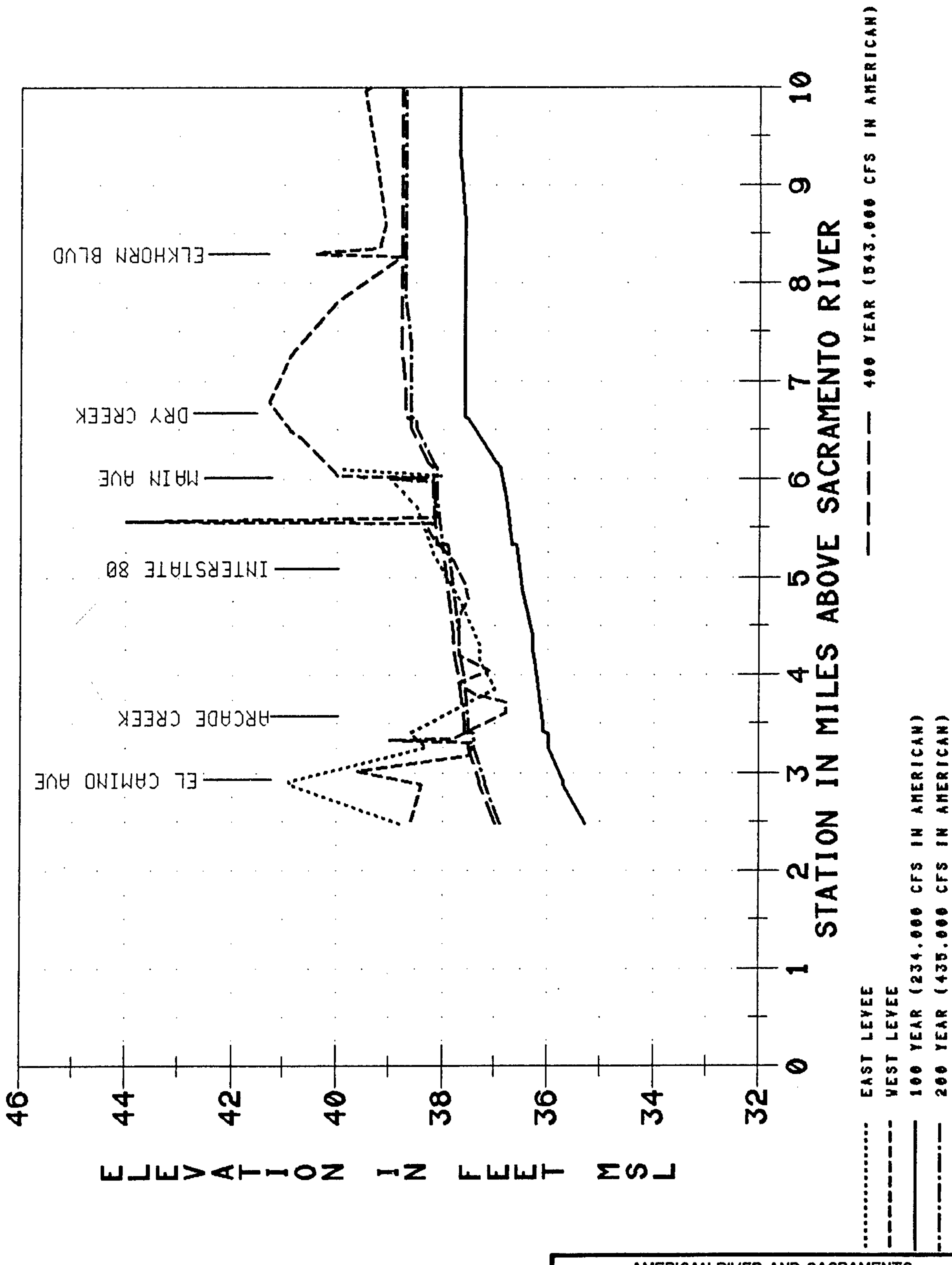
AMERICAN RIVER WITH FREEBOARD FAILURES

CORPS OF ENGINEERS, SACRAMENTO, CALIFORNIA

Prepared : J.H.
Drawn : J.H.

Date : JANUARY 1990

SHEET 2 OF 2 CHART 48



AMERICAN RIVER AND SACRAMENTO
METRO INVESTIGATIONS, CALIFORNIA

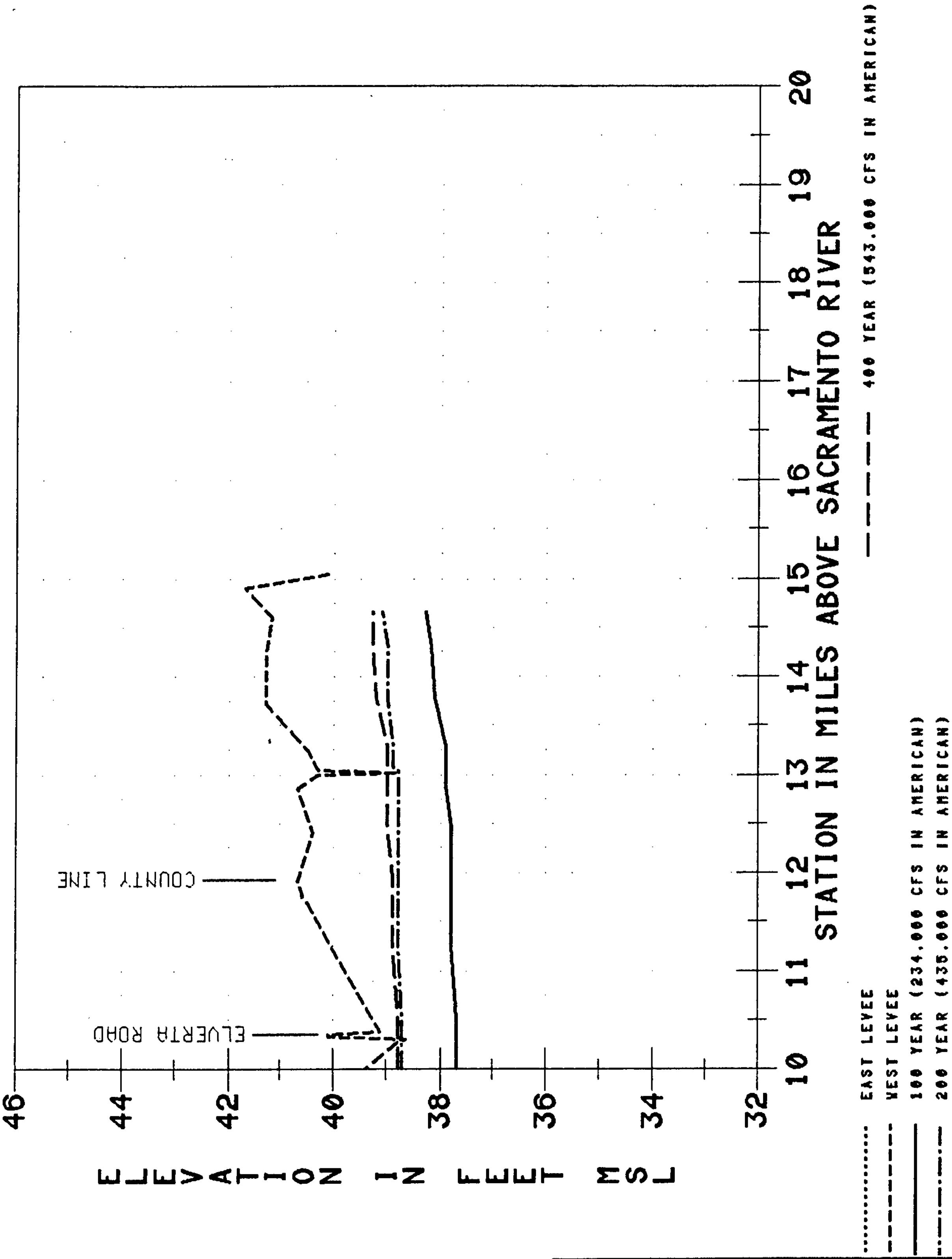
NATOMAS EAST MAIN DRAIN WITH FREEBOARD FAILURES

CORPS OF ENGINEERS, SACRAMENTO, CALIFORNIA

Prepared: J.H.
Drawn: J.H.

Date: JANUARY 1990

SHEET 1 OF 2 CHART 49



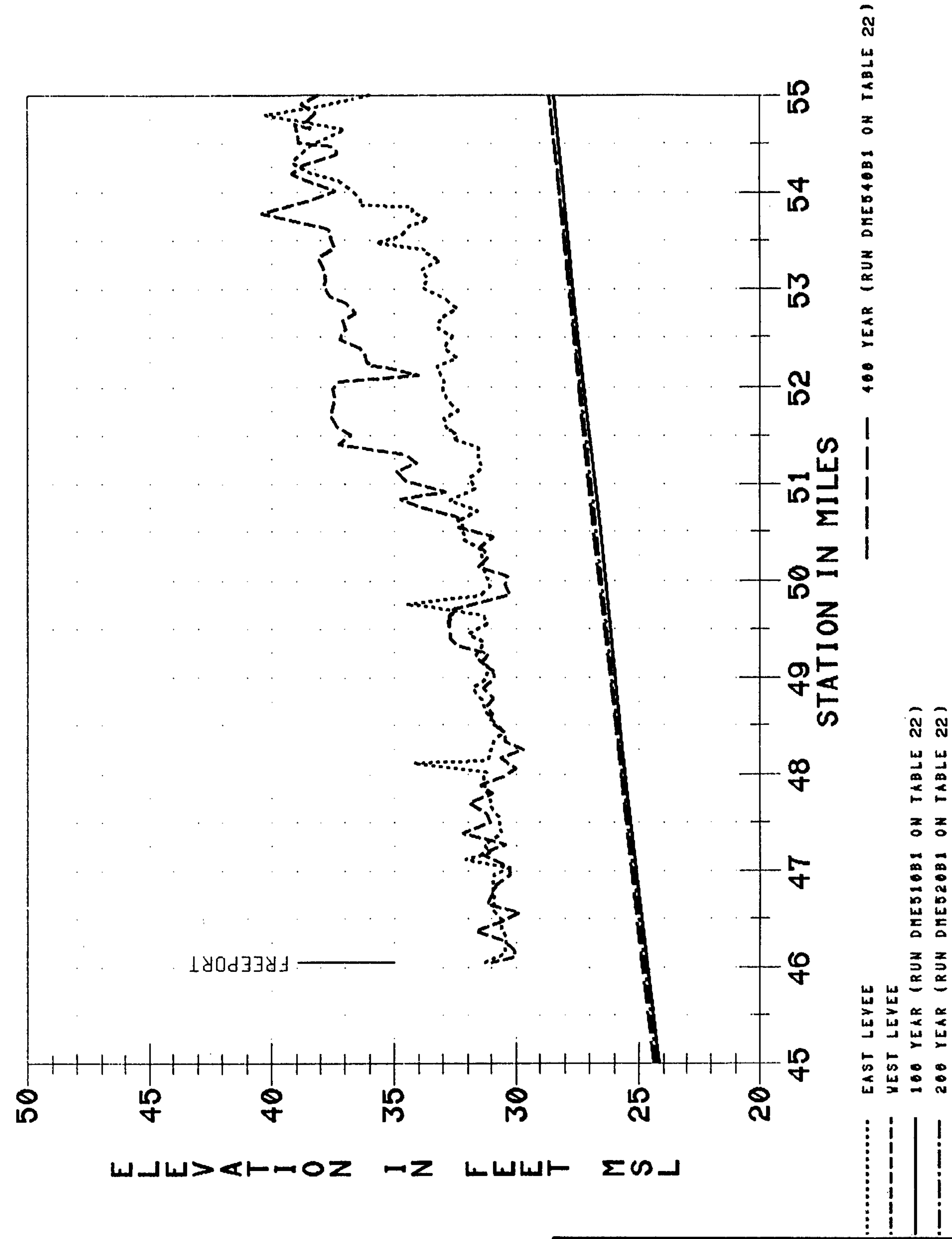
AMERICAN RIVER AND SACRAMENTO
METRO INVESTIGATIONS, CALIFORNIA

NATOMAS EAST MAIN DRAIN WITH FREEBOARD FAILURES

CORPS OF ENGINEERS, SACRAMENTO, CALIFORNIA

Prepared: J.H.
Drawn: J.H.
Date: JANUARY 1990

SHEET 2 OF 2 CHART 49



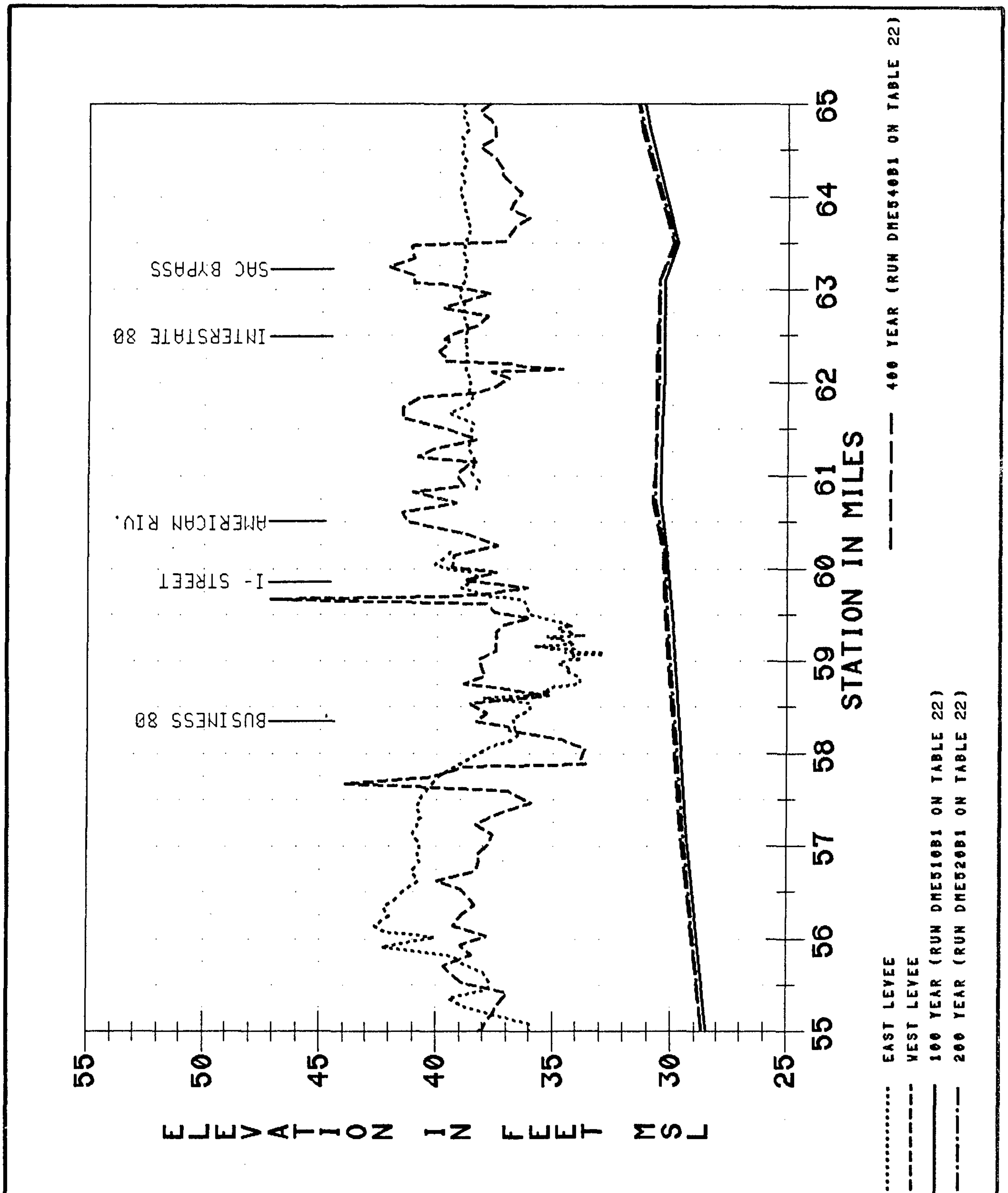
AMERICAN RIVER AND SACRAMENTO
METRO INVESTIGATIONS, CALIFORNIA

SACRAMENTO RIVER
NO FAILURES
115,000 CFS
IN AMERICAN RIVER

CORPS OF ENGINEERS. SACRAMENTO. CALIFORNIA

Prepared: J.H.
Drawn: J.H.
Date: JANUARY 1990

SHEET 1 OF 4 CHART 50



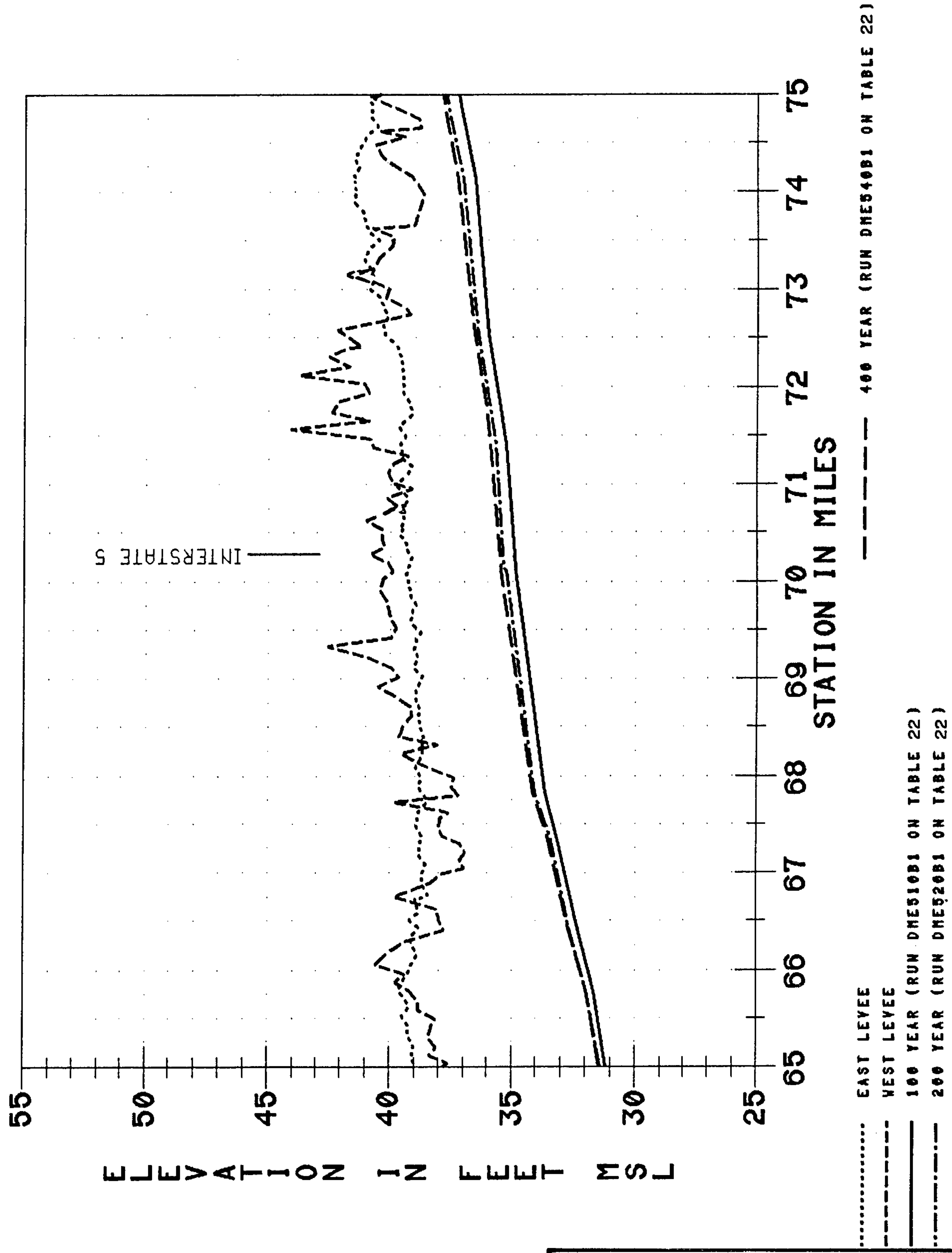
AMERICAN RIVER AND SACRAMENTO
METRO INVESTIGATIONS, CALIFORNIA

SACRAMENTO RIVER
NO FAILURES
115,000 CFS
IN AMERICAN RIVER

CORPS OF ENGINEERS. SACRAMENTO. CALIFORNIA

Prepared: J.H.
Drawn: J.H.
Date: JANUARY 1990

SHEET 2 OF 4 CHART 50



AMERICAN RIVER AND SACRAMENTO
METRO INVESTIGATIONS, CALIFORNIA

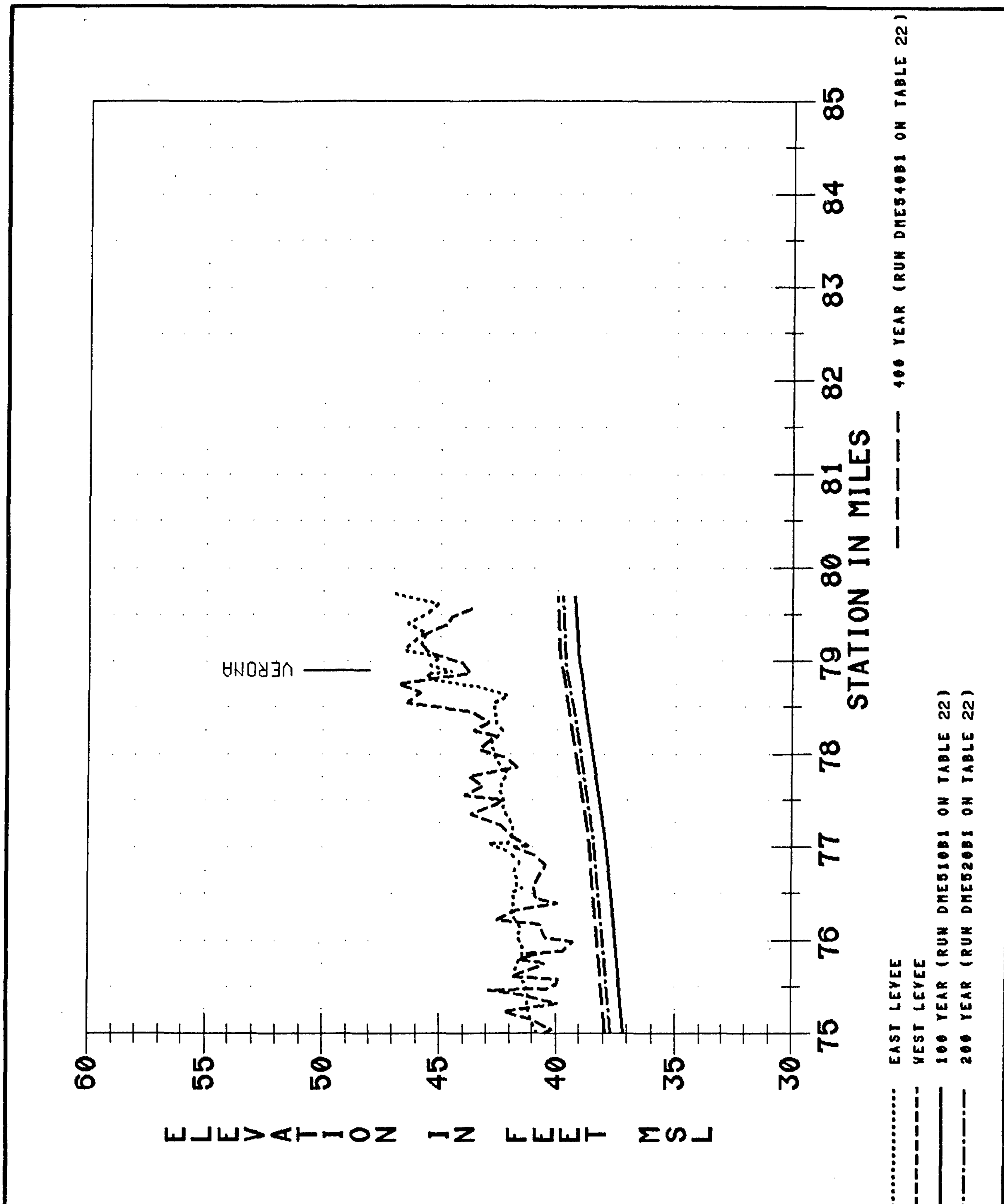
SACRAMENTO RIVER
NO FAILURES
115,000 CFS
IN AMERICAN RIVER

CORPS OF ENGINEERS. SACRAMENTO. CALIFORNIA

Prepared: J.H.
Drawn: J.H.

Date: JANUARY 1990

SHEET 3 OF 4 CHART 50



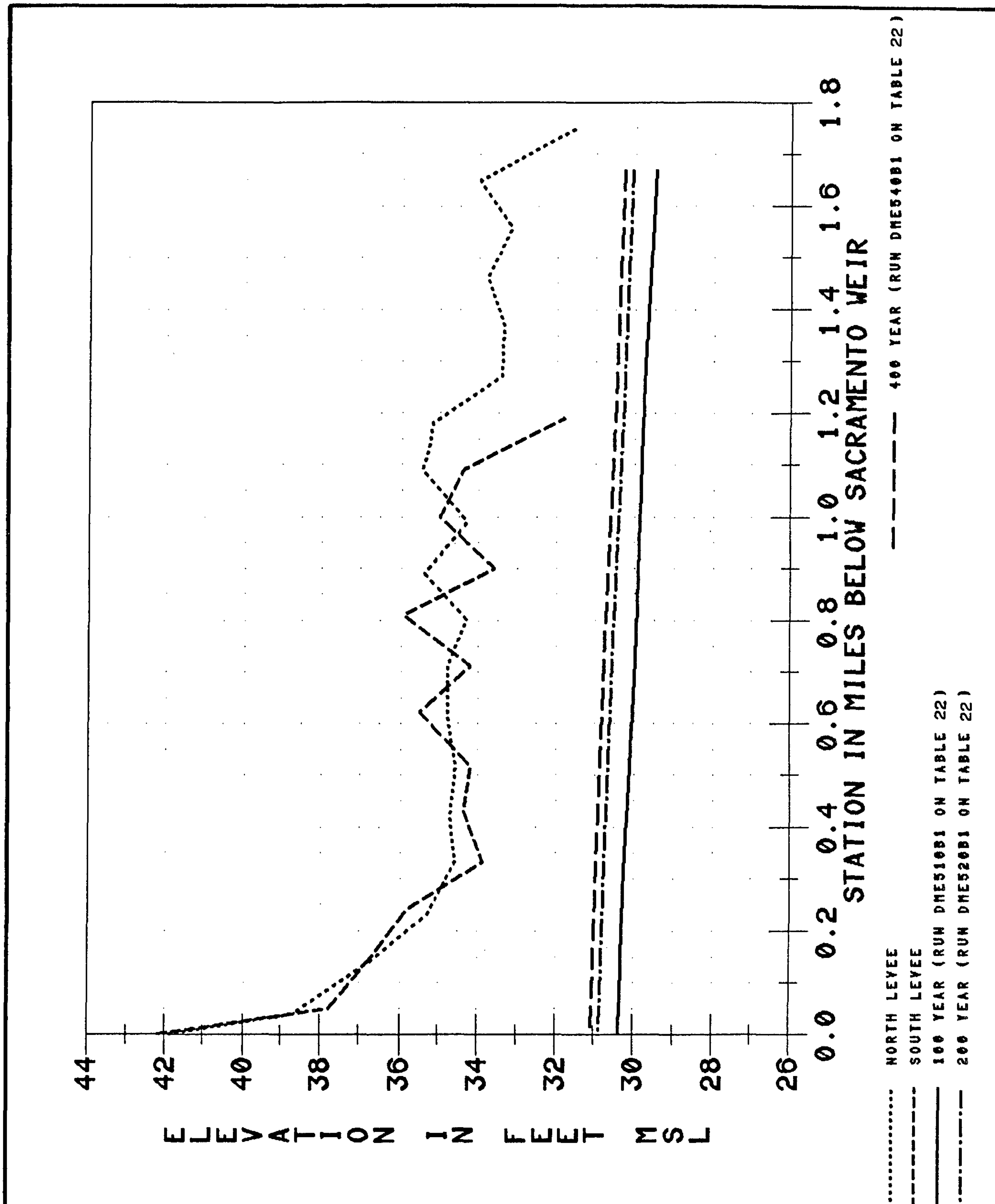
AMERICAN RIVER AND SACRAMENTO
METRO INVESTIGATIONS, CALIFORNIA

SACRAMENTO RIVER
NO FAILURES
115,000 CFS
IN AMERICAN RIVER

CORPS OF ENGINEERS. SACRAMENTO. CALIFORNIA

Prepared: J.H.
Drawn: J.H.
Date: JANUARY 1990

SHEET 4 OF 4 CHART 50



AMERICAN RIVER AND SACRAMENTO
METRO INVESTIGATIONS, CALIFORNIA

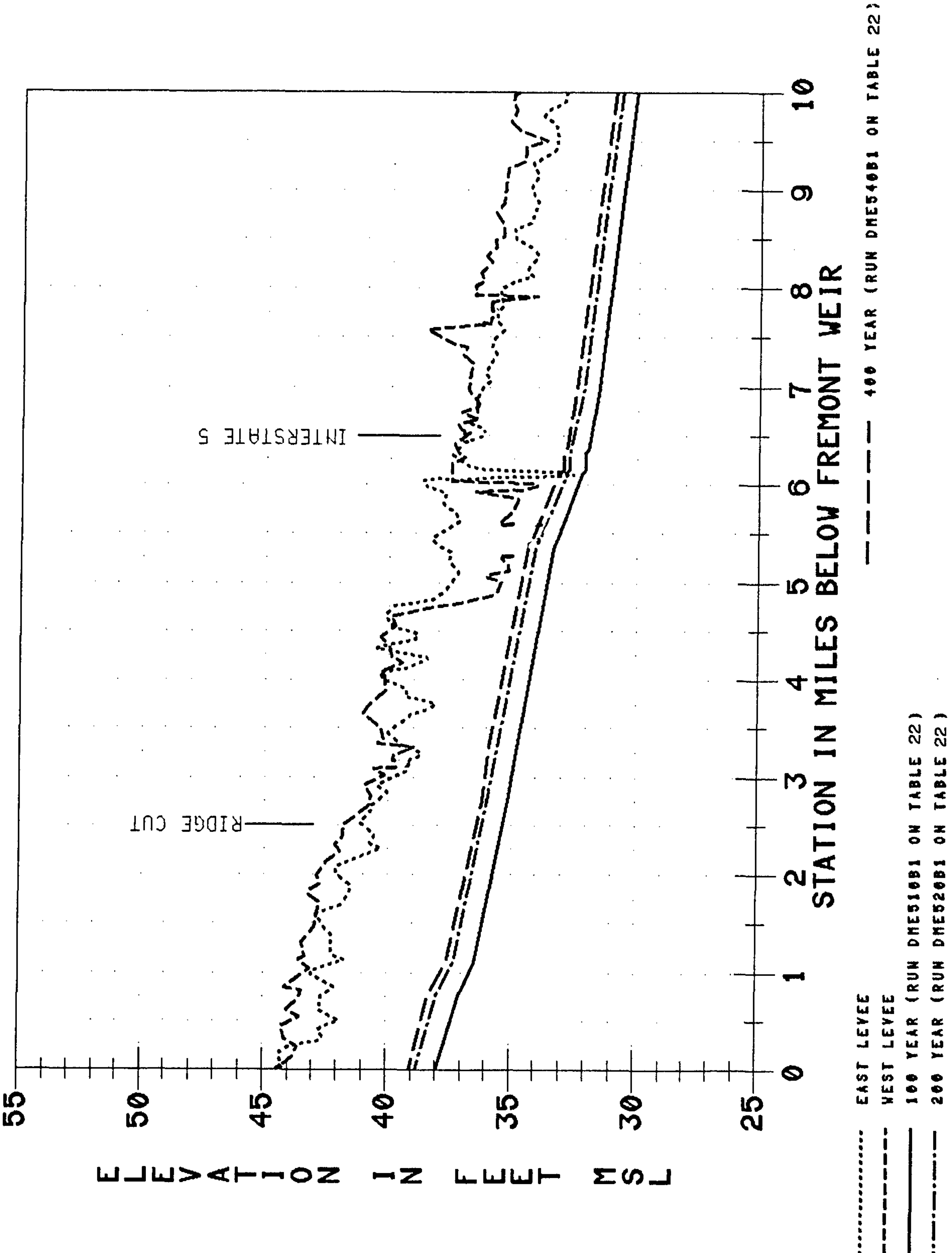
SACRAMENTO BYPASS
NO FAILURES
115,000 CFS
IN AMERICAN RIVER

CORPS OF ENGINEERS. SACRAMENTO. CALIFORNIA

Prepared: J.H.
Drawn: J.H.

Date: JANUARY 1990

CHART 51



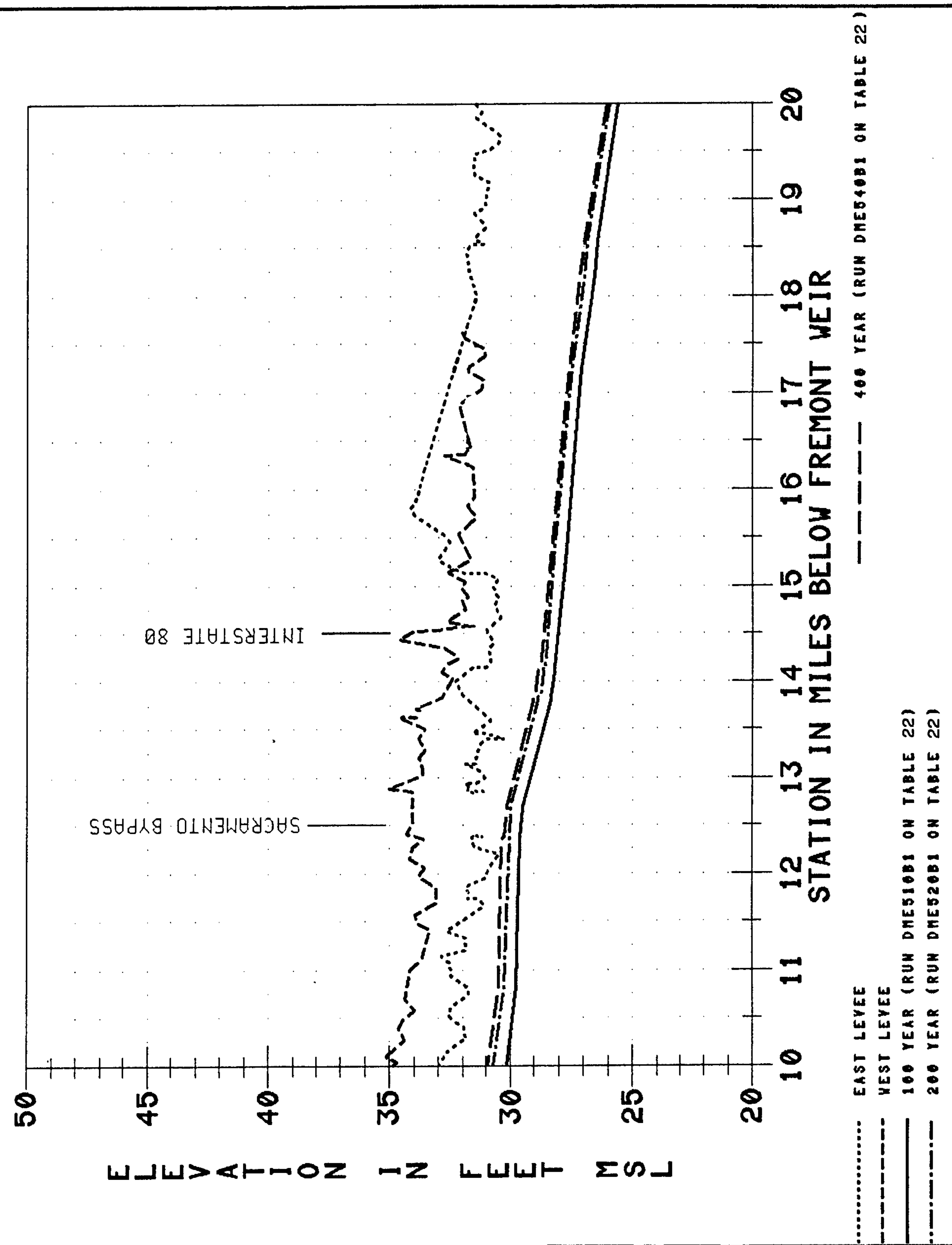
AMERICAN RIVER AND SACRAMENTO
METRO INVESTIGATIONS, CALIFORNIA

YOLO BYPASS
NO FAILURES
115,000 CFS
IN AMERICAN RIVER

CORPS OF ENGINEERS, SACRAMENTO, CALIFORNIA

Prepared: J.H.
Drawn: J.H.
Date: JANUARY 1990

SHEET 1 OF 3 CHART 52



AMERICAN RIVER AND SACRAMENTO
METRO INVESTIGATIONS, CALIFORNIA

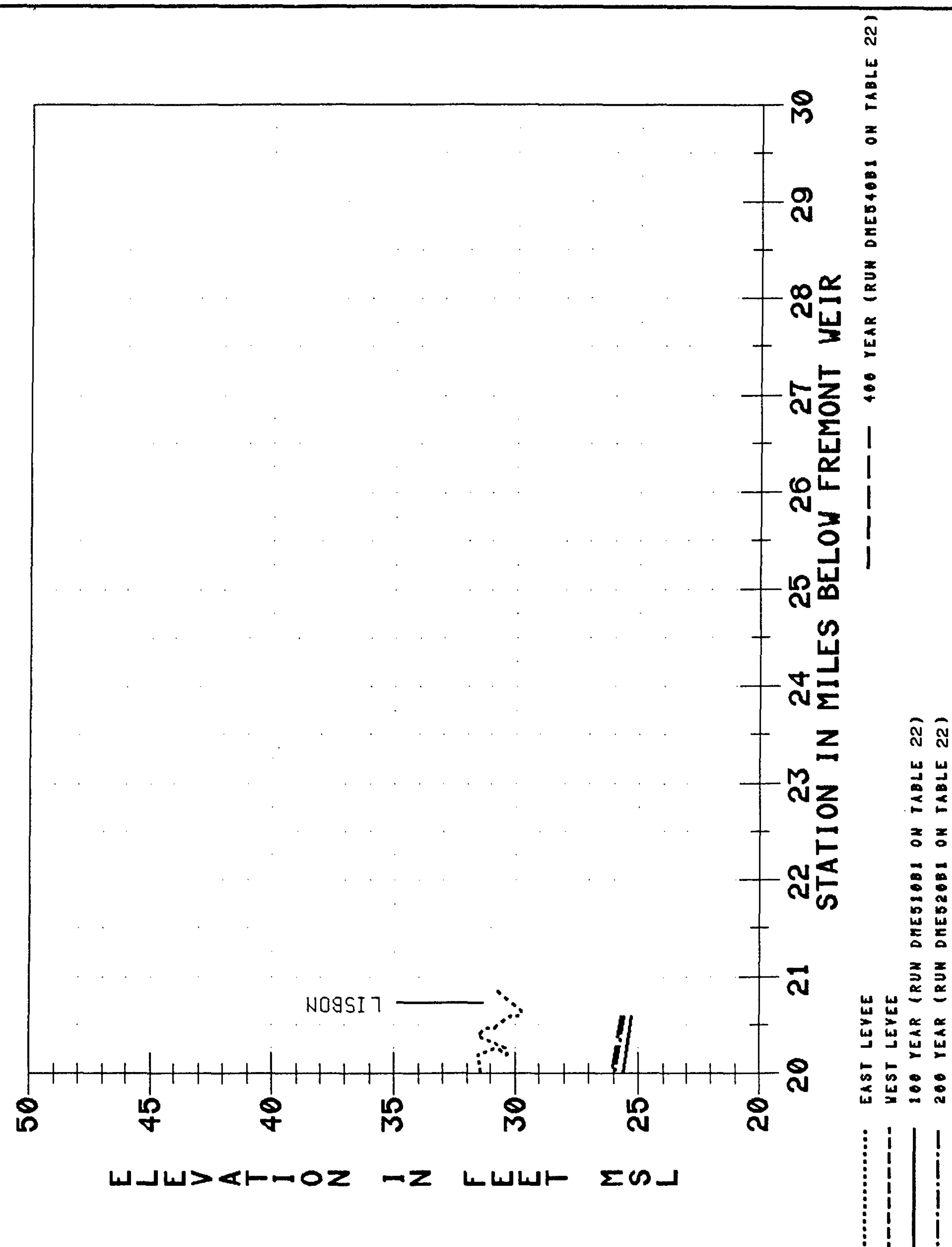
YOLO BYPASS
NO FAILURES
115,000 CFS
IN AMERICAN RIVER

CORPS OF ENGINEERS. SACRAMENTO. CALIFORNIA

Prepared: J.H.
Drawn: J.H.

Date: JANUARY 1990

SHEET 2 OF 3 CHART 52



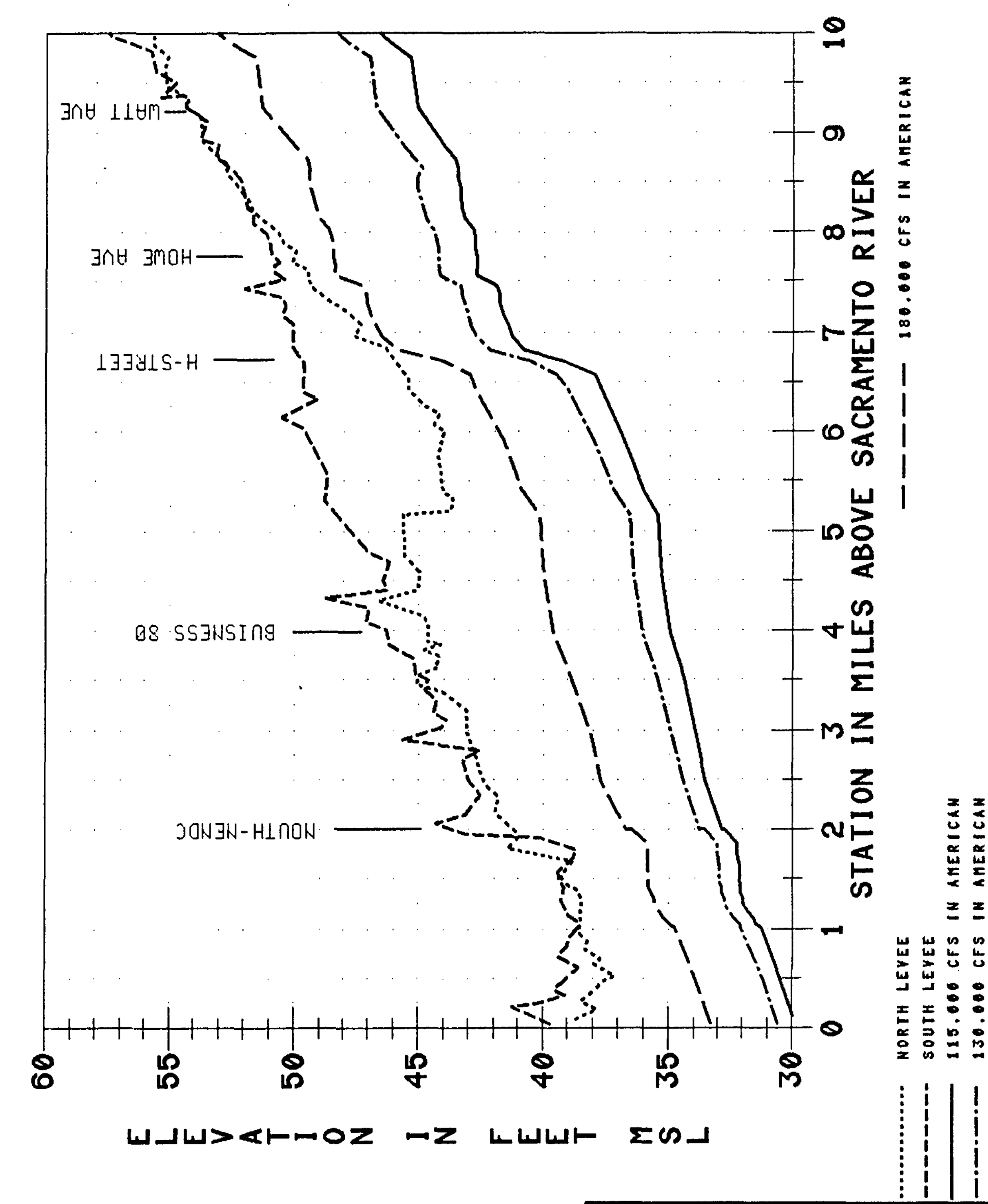
AMERICAN RIVER AND SACRAMENTO
METRO INVESTIGATIONS, CALIFORNIA

YOLO BYPASS
NO FAILURES
115,000 CFS
IN AMERICAN RIVER

CORPS OF ENGINEERS. SACRAMENTO. CALIFORNIA

Prepared: J.H.
Drawn: J.H.
Date: JANUARY 1990

SHEET 3 OF 3 CHART 52



AMERICAN RIVER AND SACRAMENTO
METRO INVESTIGATIONS, CALIFORNIA

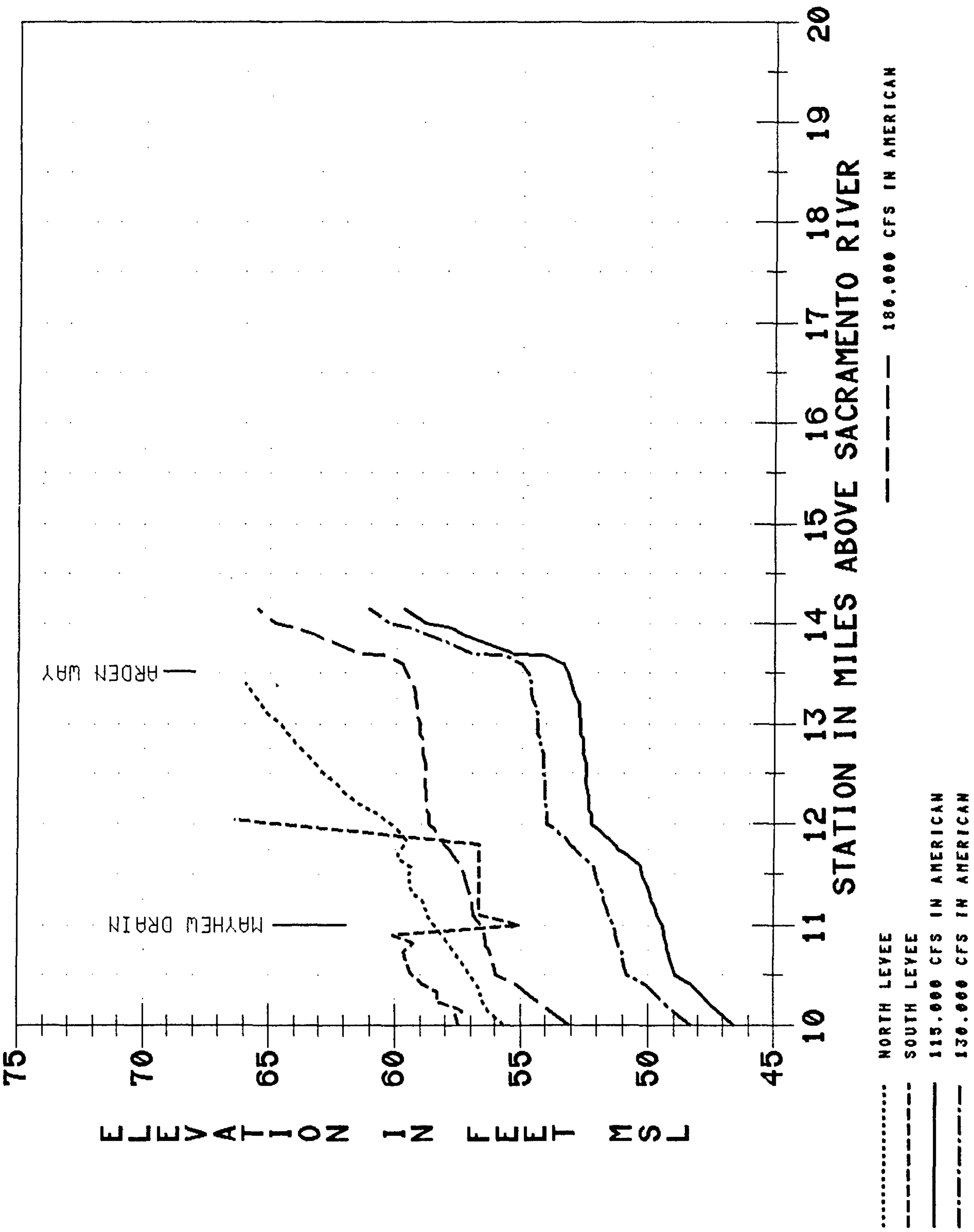
AMERICAN RIVER
NO FAILURES

CORPS OF ENGINEERS. SACRAMENTO. CALIFORNIA

Prepared: J.H.
Drawn: J.H.

Date: JANUARY 1990

SHEET 1 OF 2 CHART 53



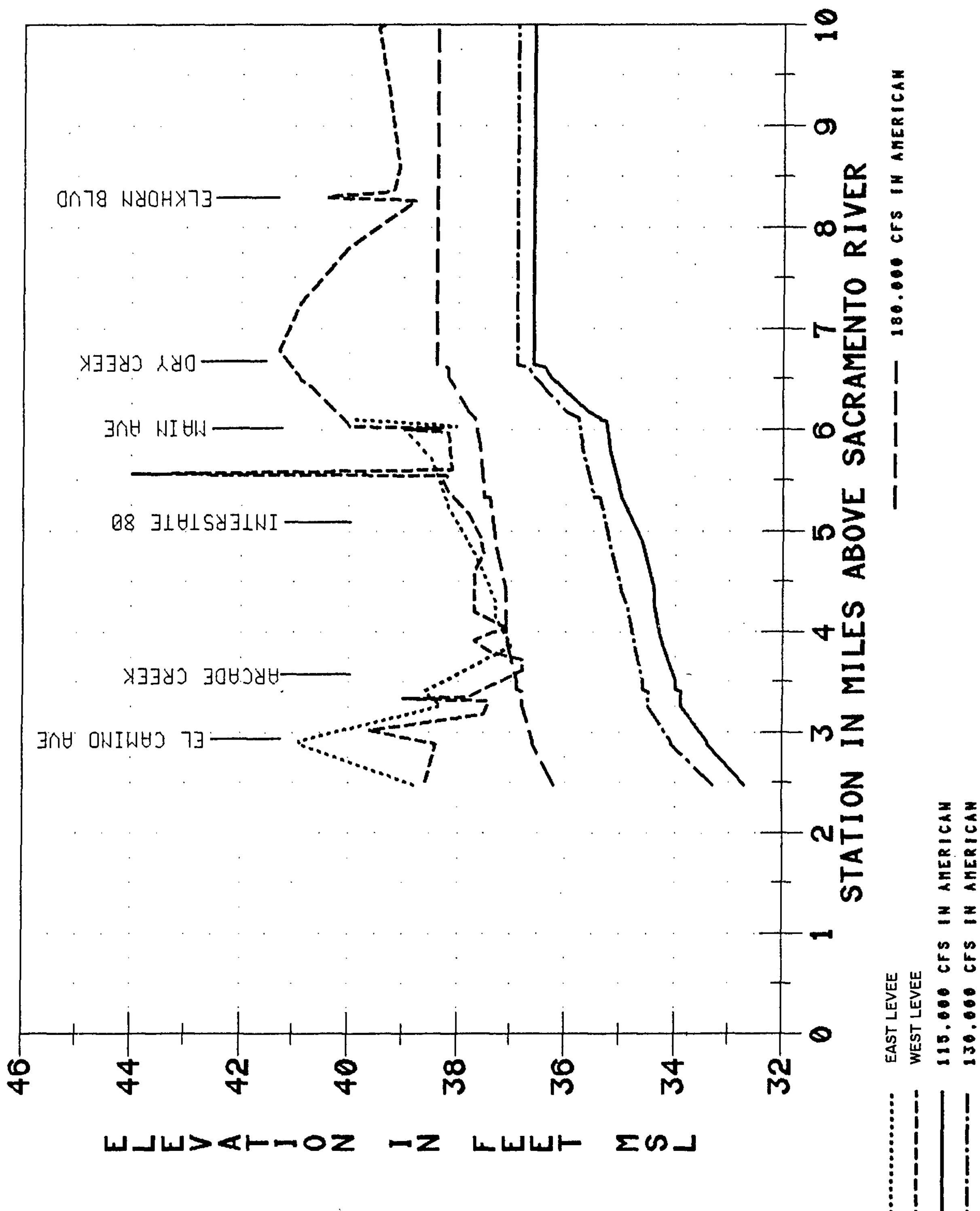
AMERICAN RIVER AND SACRAMENTO
METRO INVESTIGATIONS, CALIFORNIA

AMERICAN RIVER
NO FAILURES

CORPS OF ENGINEERS. SACRAMENTO. CALIFORNIA

Prepared: J.H.
Drawn: J.H.
Date: JANUARY 1990

SHEET 2 OF 2 CHART 53



AMERICAN RIVER AND SACRAMENTO
METRO INVESTIGATIONS, CALIFORNIA

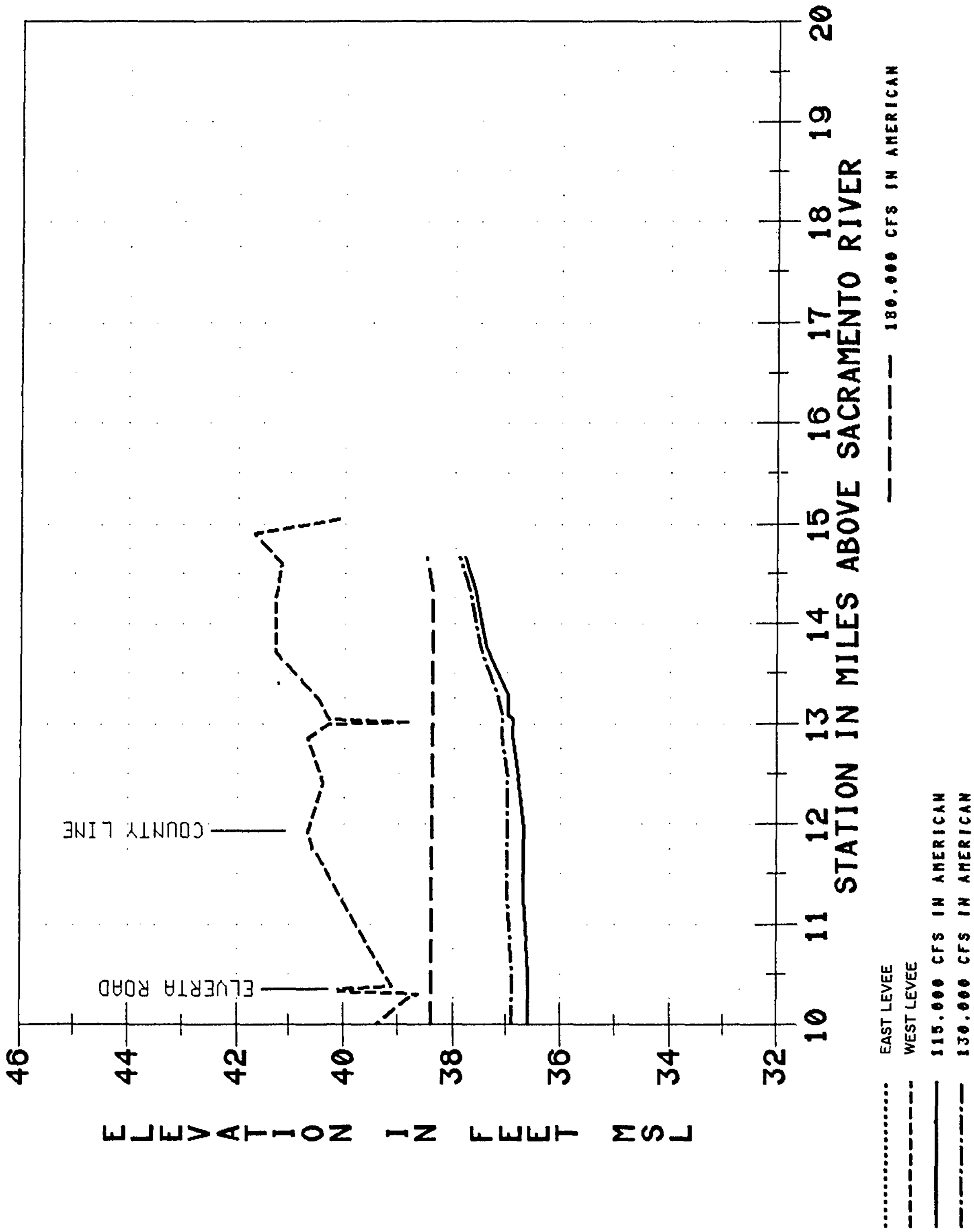
NATOMAS EAST MAIN DRAIN
NO FAILURES

CORPS OF ENGINEERS. SACRAMENTO. CALIFORNIA

Prepared : J.H.
Drawn : J.H.

Date : JANUARY 1990

SHEET I OF 2 CHART 54



AMERICAN RIVER AND SACRAMENTO
METRO INVESTIGATIONS, CALIFORNIA

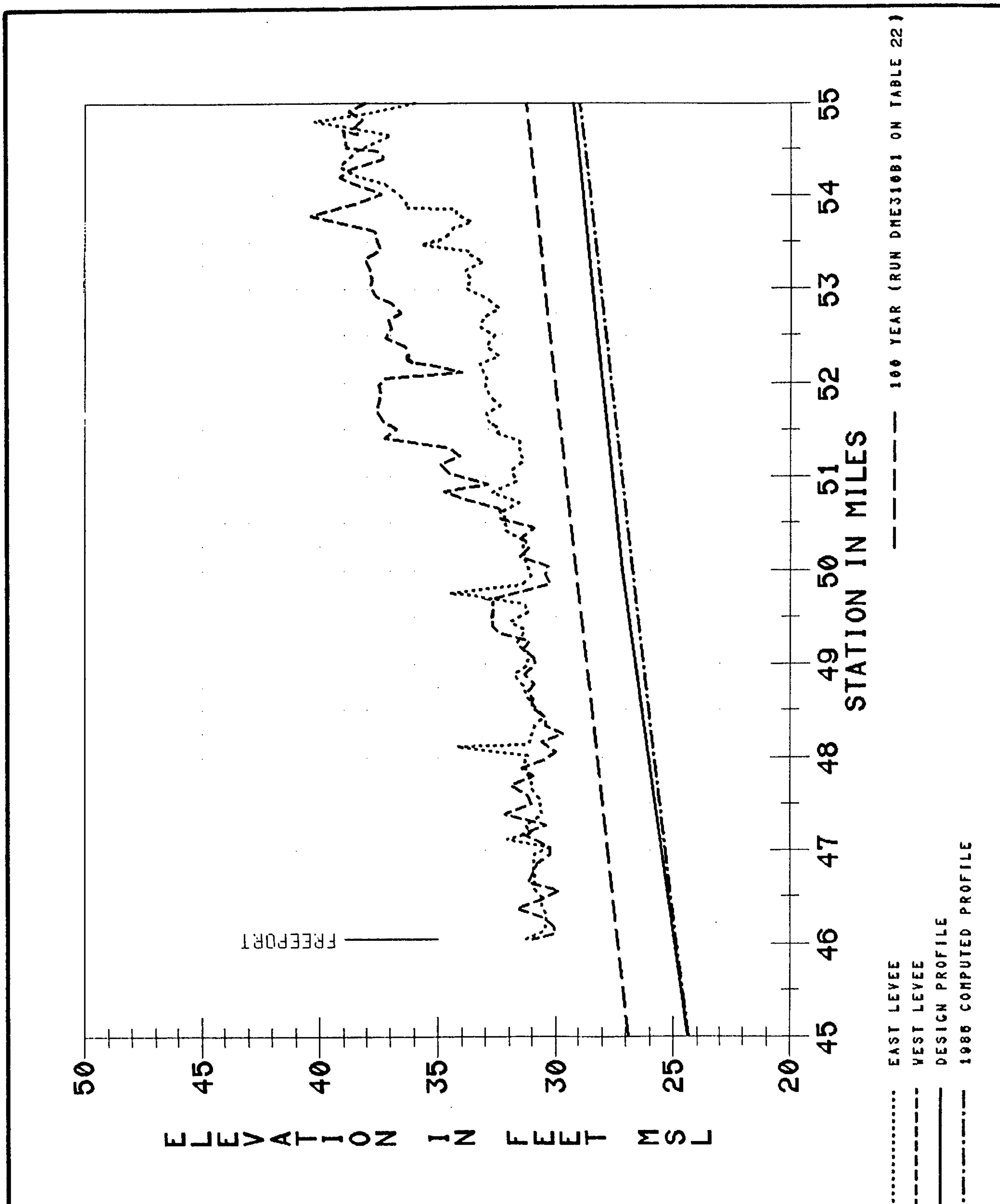
NATOMAS EAST MAIN DRAIN
NO FAILURES

CORPS OF ENGINEERS. SACRAMENTO. CALIFORNIA

Prepared: J.H.
Drawn: J.H.

Date: JANUARY 1990

SHEET 2 OF 2 CHART 54



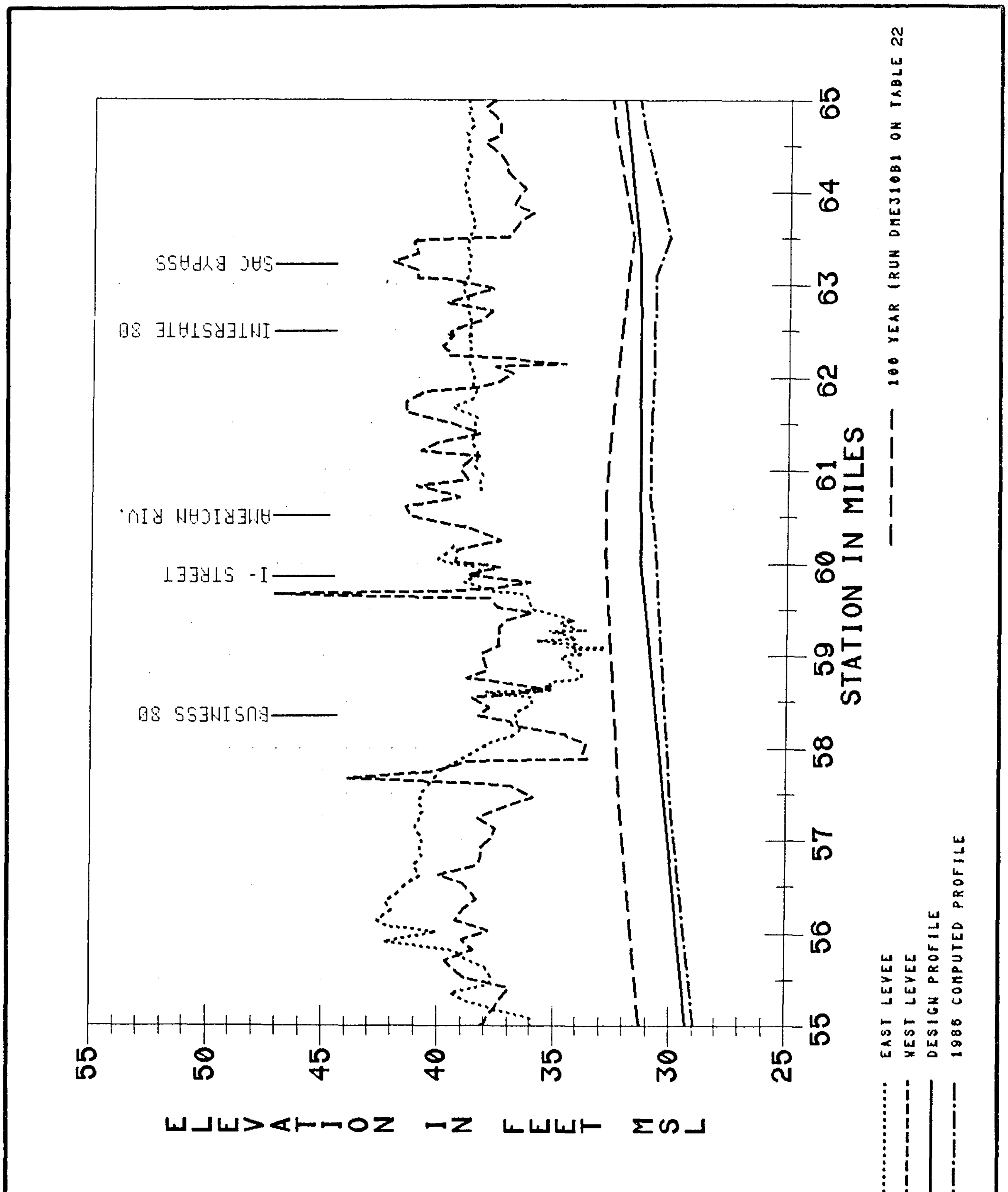
AMERICAN RIVER AND SACRAMENTO
METRO INVESTIGATIONS, CALIFORNIA

DESIGN PROFILE COMPARISON
SACRAMENTO RIVER

CORPS OF ENGINEERS. SACRAMENTO. CALIFORNIA

Prepared: J.H.
Drawn: J.H.
Date: JANUARY 1990

SHEET I OF 4 CHART 55



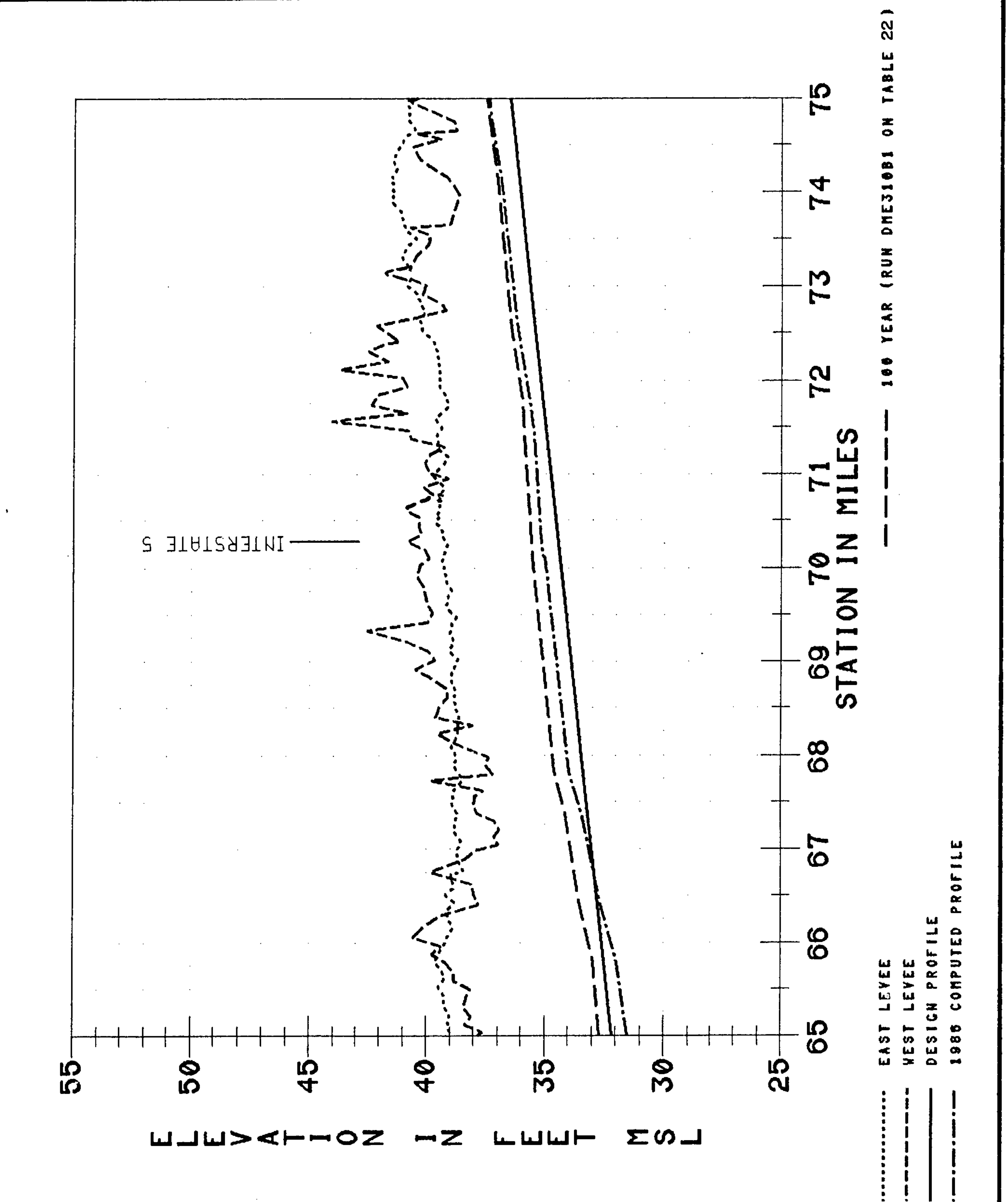
AMERICAN RIVER AND SACRAMENTO
METRO INVESTIGATIONS, CALIFORNIA

DESIGN PROFILE COMPARISON
SACRAMENTO RIVER

CORPS OF ENGINEERS. SACRAMENTO. CALIFORNIA

Prepared: J.H.
Drawn: J.H.

Date: JANUARY 1990



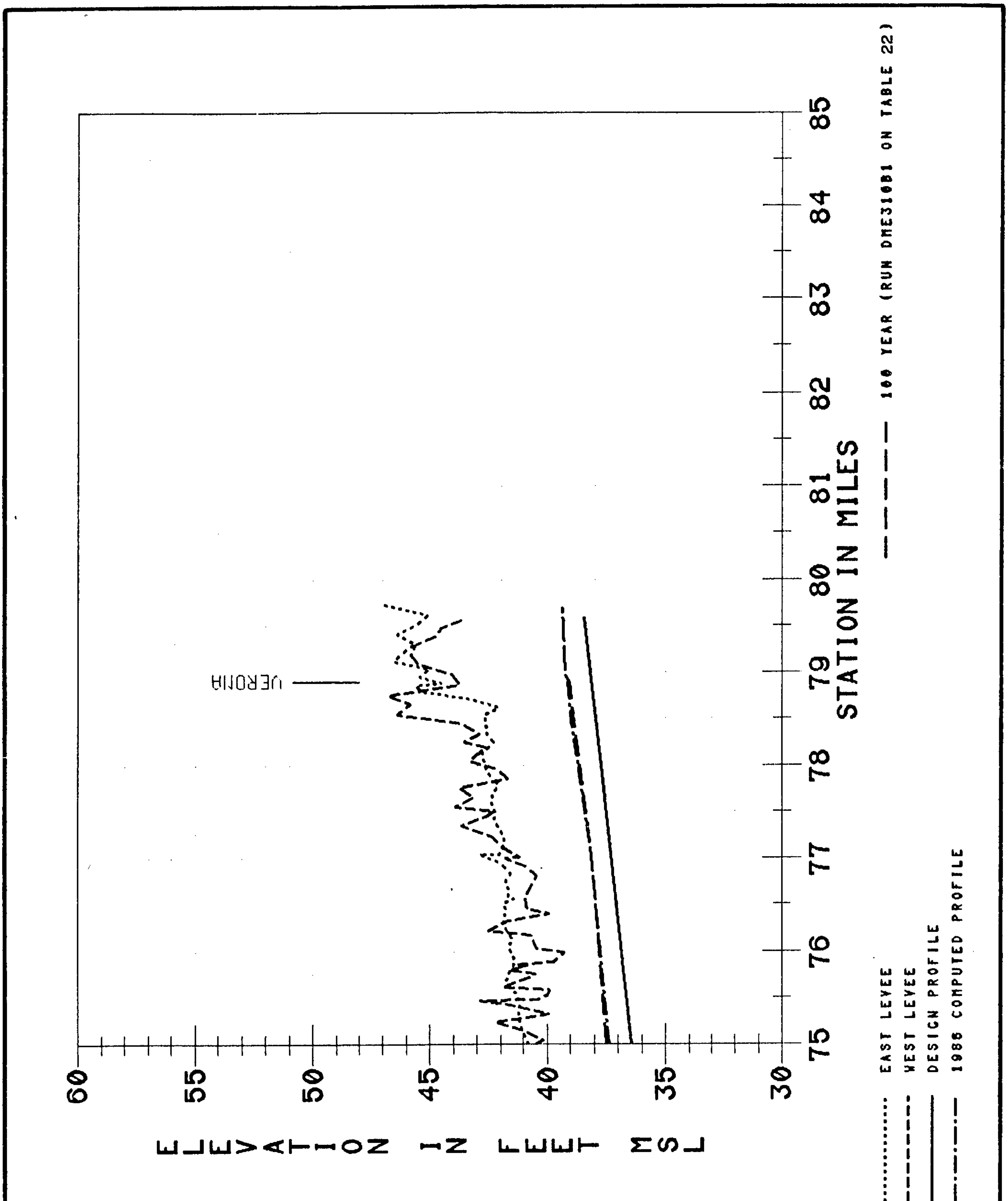
AMERICAN RIVER AND SACRAMENTO
METRO INVESTIGATIONS, CALIFORNIA

DESIGN PROFILE COMPARISON
SACRAMENTO RIVER

CORPS OF ENGINEERS. SACRAMENTO. CALIFORNIA

Prepared: J.H.
Drawn: J.H.
Date: JANUARY 1990

SHEET 3 OF 4 CHART 55



AMERICAN RIVER AND SACRAMENTO
METRO INVESTIGATIONS, CALIFORNIA

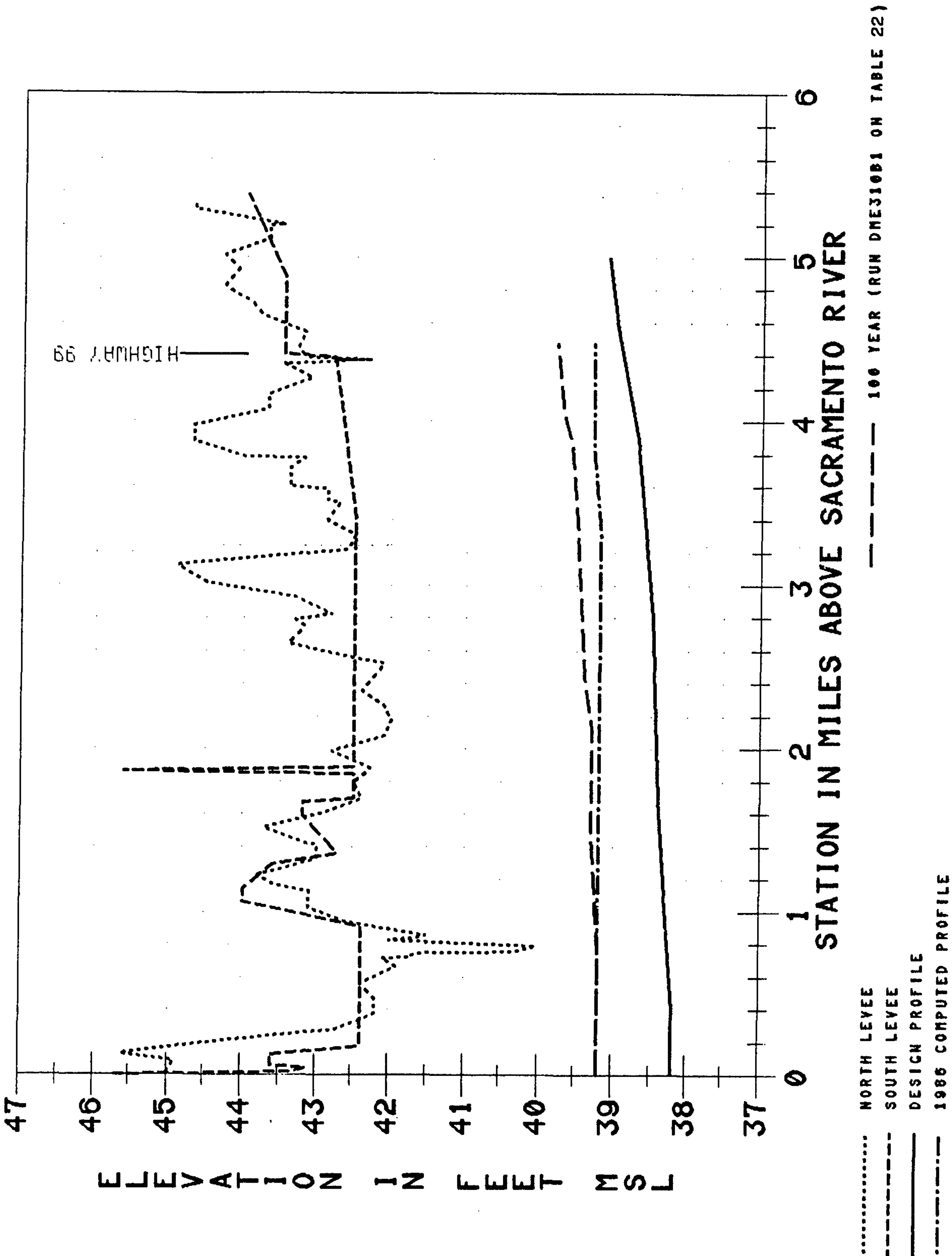
DESIGN PROFILE COMPARISON
SACRAMENTO RIVER

CORPS OF ENGINEERS. SACRAMENTO. CALIFORNIA

Prepared: J.H.
Drawn: J.H.

Date: JANUARY 1990

SHEET 4 OF 4 CHART 55



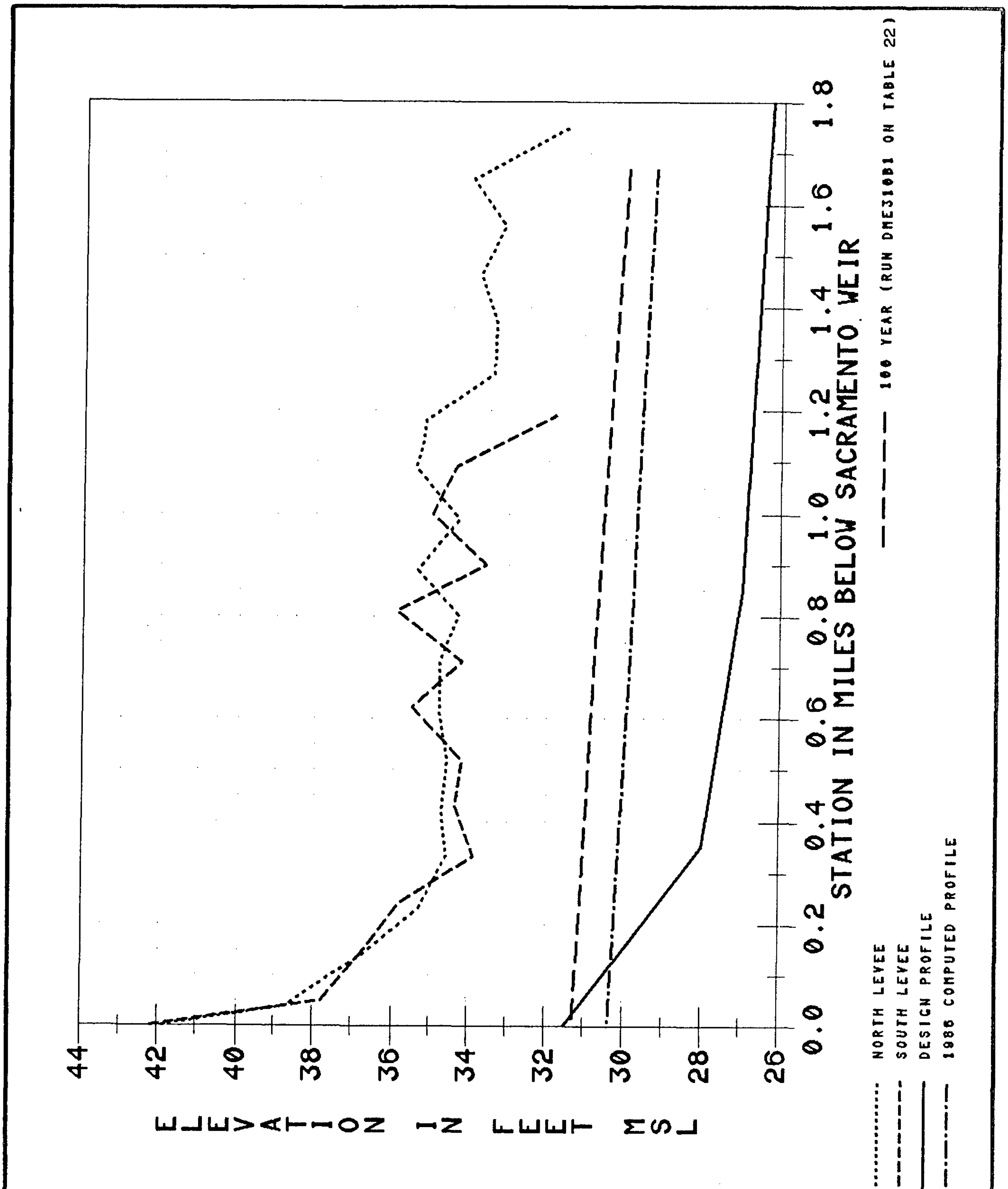
AMERICAN RIVER AND SACRAMENTO
METRO INVESTIGATIONS, CALIFORNIA

DESIGN PROFILE COMPARISON NATOMAS CROSS CANAL

CORPS OF ENGINEERS. SACRAMENTO. CALIFORNIA

Prepared: J.H.
Drawn: J.H.
Date: JANUARY 1990

CHART 56



AMERICAN RIVER AND SACRAMENTO
METRO INVESTIGATIONS, CALIFORNIA

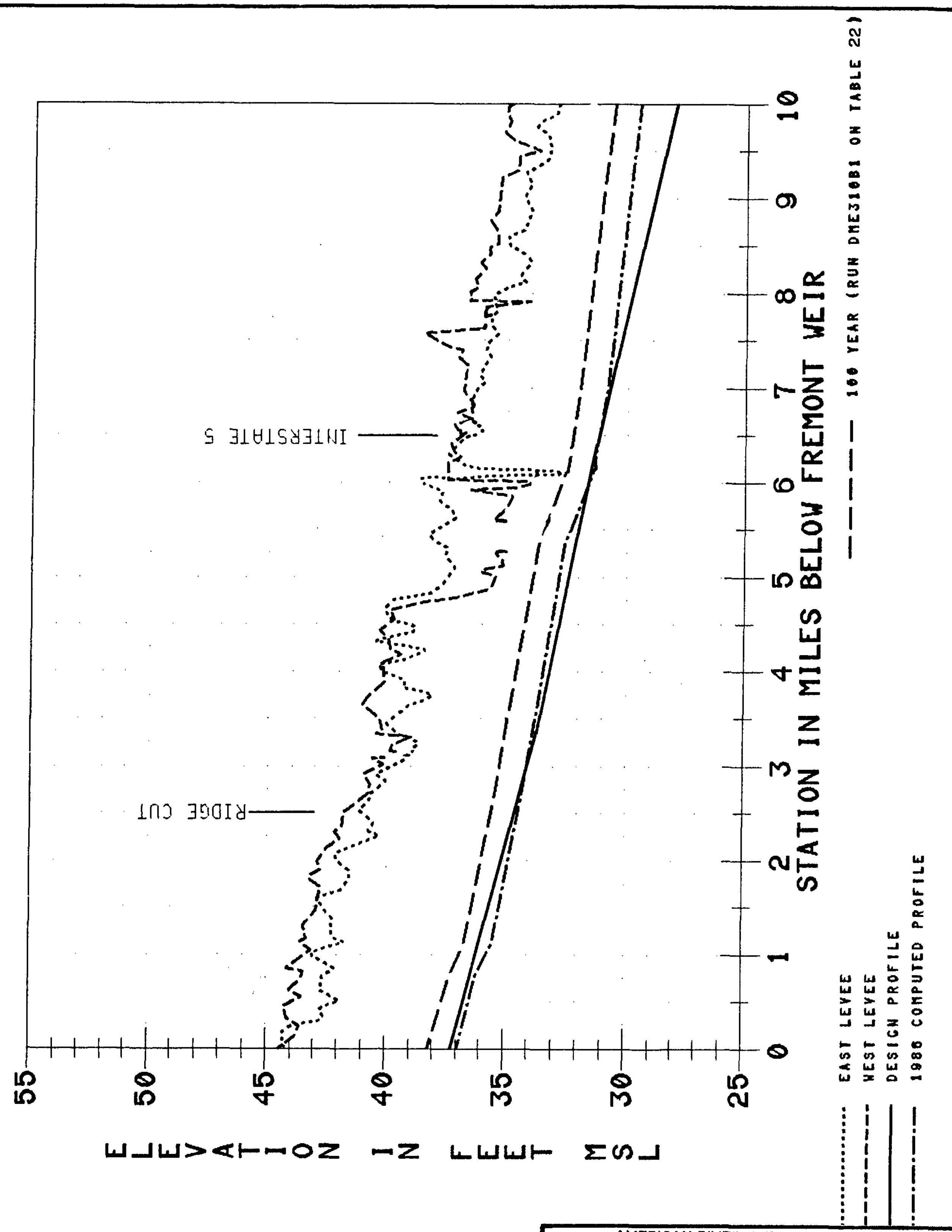
DESIGN PROFILE COMPARISON
SACRAMENTO BYPASS

CORPS OF ENGINEERS. SACRAMENTO. CALIFORNIA

Prepared: J.H.
Drawn: J.H.

Date: JANUARY 1990

CHART 57



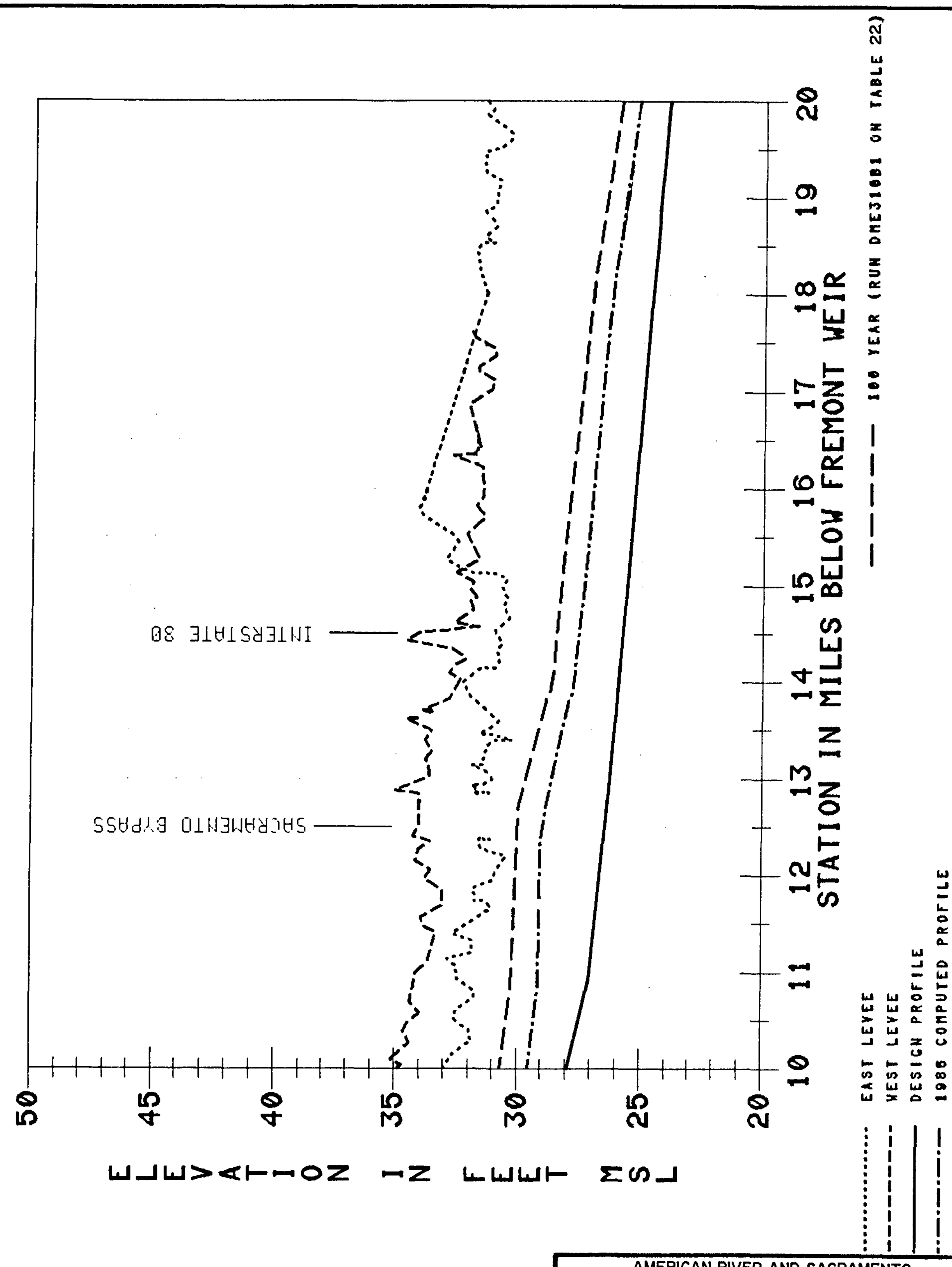
AMERICAN RIVER AND SACRAMENTO
METRO INVESTIGATIONS, CALIFORNIA

DESIGN PROFILE COMPARISON
YOLO BYPASS

CORPS OF ENGINEERS. SACRAMENTO. CALIFORNIA

Prepared: J.H.
Drawn: J.H.
Date: JANUARY 1990

SHEET I OF 3 CHART 58



AMERICAN RIVER AND SACRAMENTO
METRO INVESTIGATIONS, CALIFORNIA

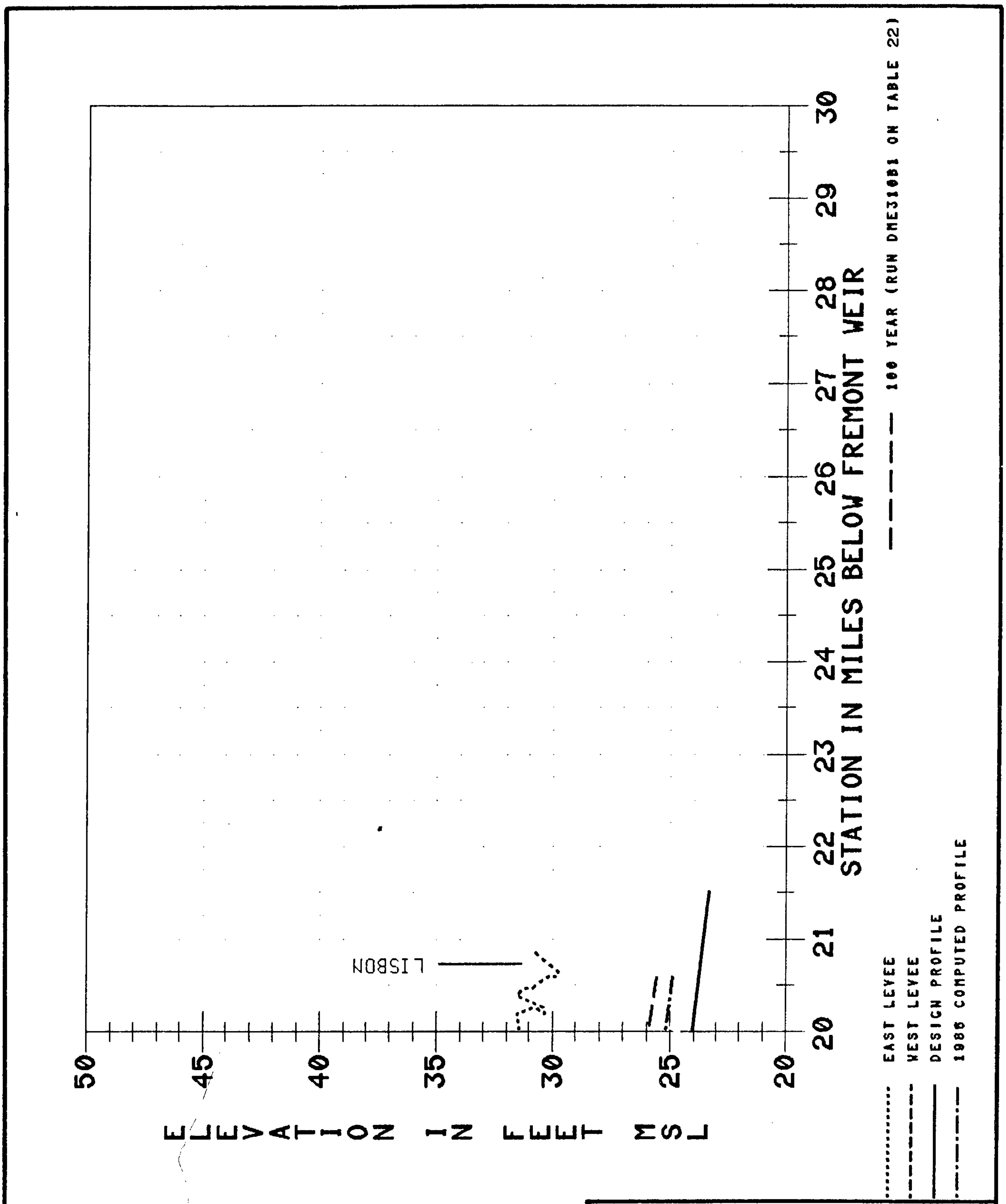
DESIGN PROFILE COMPARISON
YOLO BYPASS

CORPS OF ENGINEERS. SACRAMENTO. CALIFORNIA

Prepared: J.H.
Drawn: J.H.

Date: JANUARY 1990

SHEET 2 OF 3 CHART 58



AMERICAN RIVER AND SACRAMENTO
METRO INVESTIGATIONS, CALIFORNIA

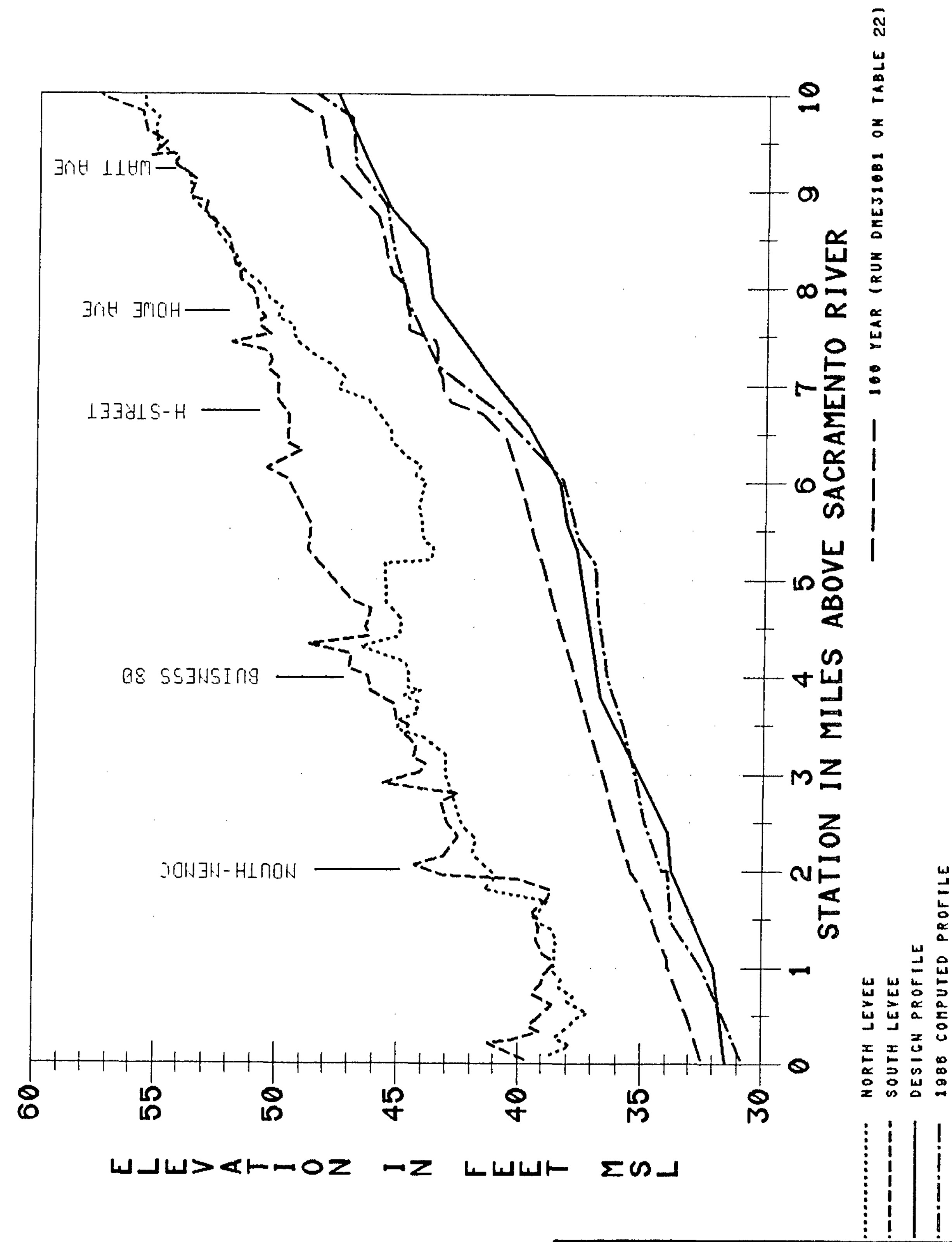
DESIGN PROFILE COMPARISON
YOLO BYPASS

CORPS OF ENGINEERS. SACRAMENTO. CALIFORNIA

Prepared: J.H.
Drawn: J.H.

Date: JANUARY 1990

SHEET 3 OF 3 CHART 58



AMERICAN RIVER AND SACRAMENTO
METRO INVESTIGATIONS, CALIFORNIA

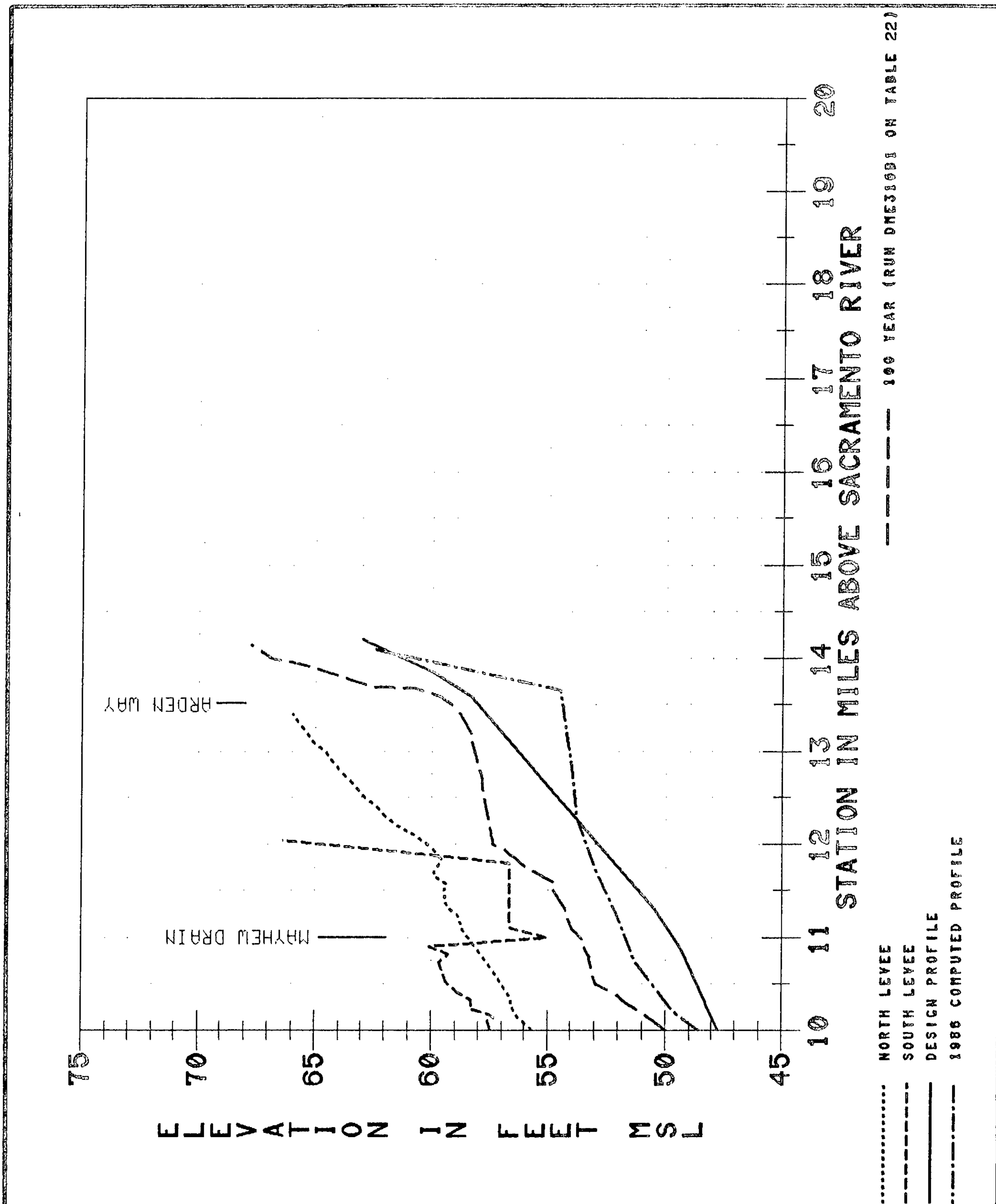
DESIGN PROFILE COMPARISON AMERICAN RIVER

CORPS OF ENGINEERS. SACRAMENTO. CALIFORNIA

Prepared: J.H.
Drawn: J.H.

Date: JANUARY 1990

SHEET 1 OF 2 CHART 59



AMERICAN RIVER AND SACRAMENTO
METRO INVESTIGATIONS, CALIFORNIA

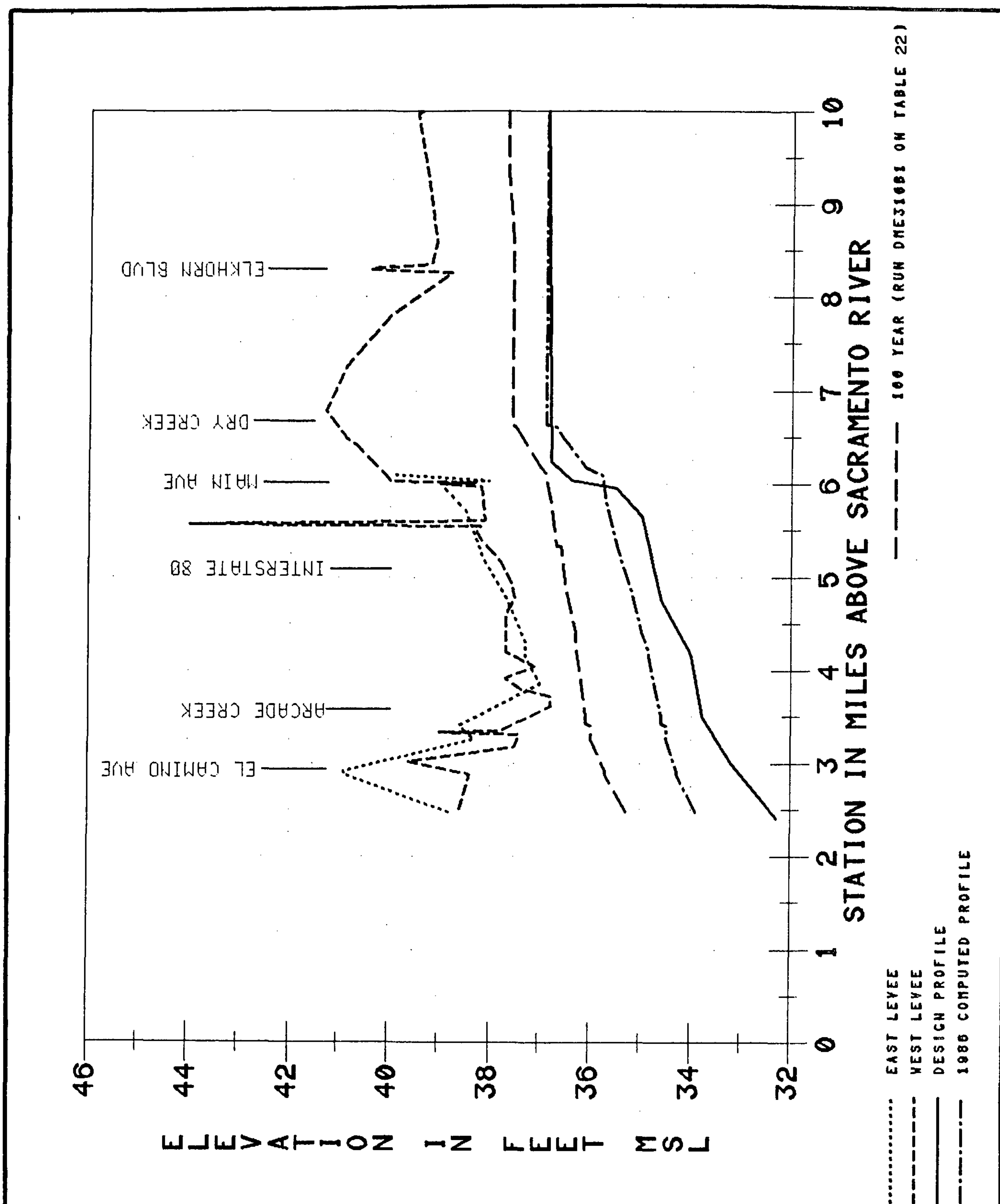
DESIGN PROFILE COMPARISON AMERICAN RIVER

CORPS OF ENGINEERS. SACRAMENTO. CALIFORNIA

Prepared: J.H.
Drawn: J.H.

Date: JANUARY 1990

SHEET 2 OF 2 CHART 59



AMERICAN RIVER AND SACRAMENTO
METRO INVESTIGATIONS, CALIFORNIA

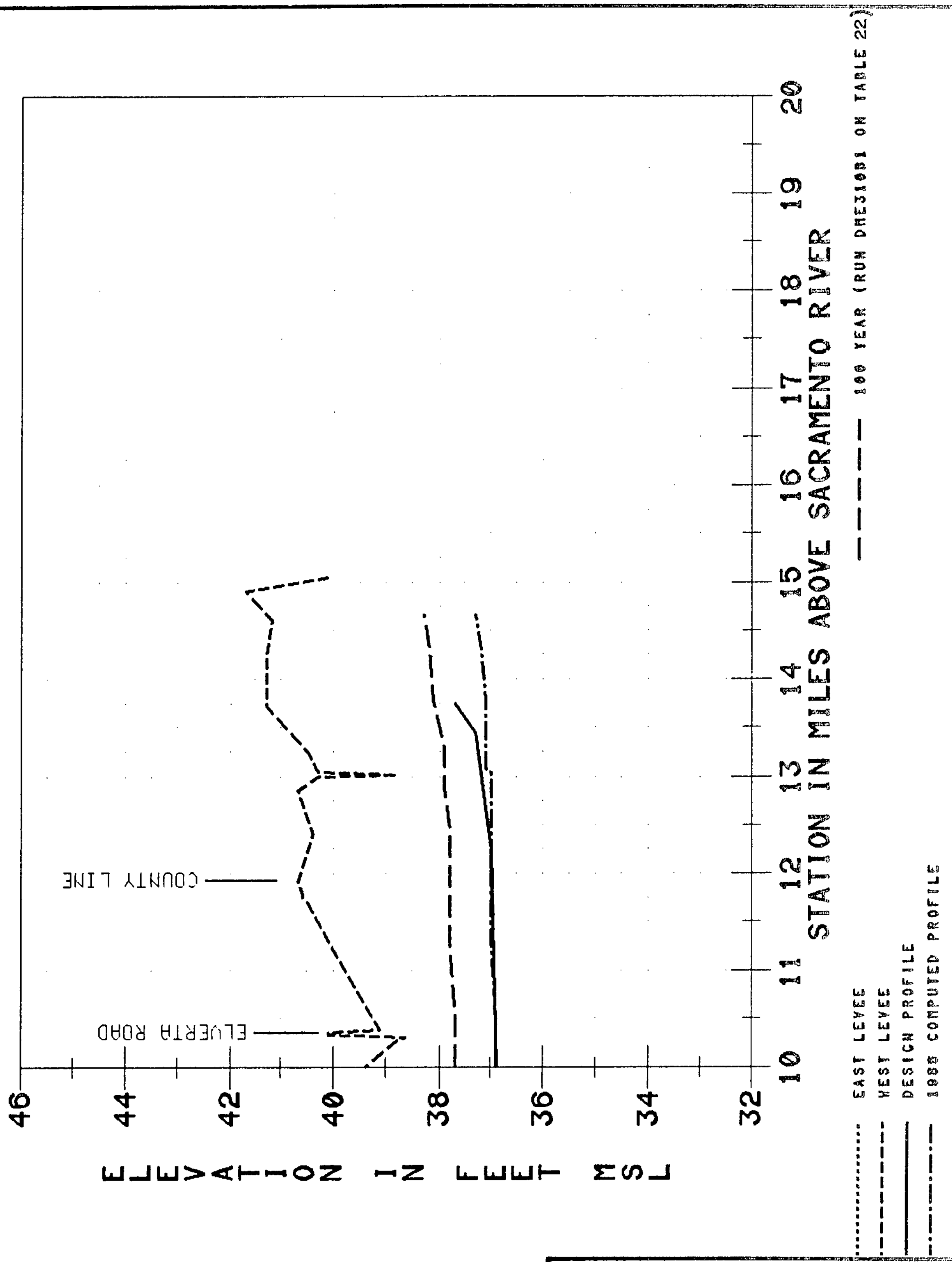
DESIGN PROFILE COMPARISON
NATOMAS EAST MAIN DRAIN

CORPS OF ENGINEERS, SACRAMENTO, CALIFORNIA

Prepared: J.H.
Drawn: J.H.

Date: JANUARY 1990

SHEET 1 OF 2 CHART 60



AMERICAN RIVER AND SACRAMENTO
METRO INVESTIGATIONS, CALIFORNIA

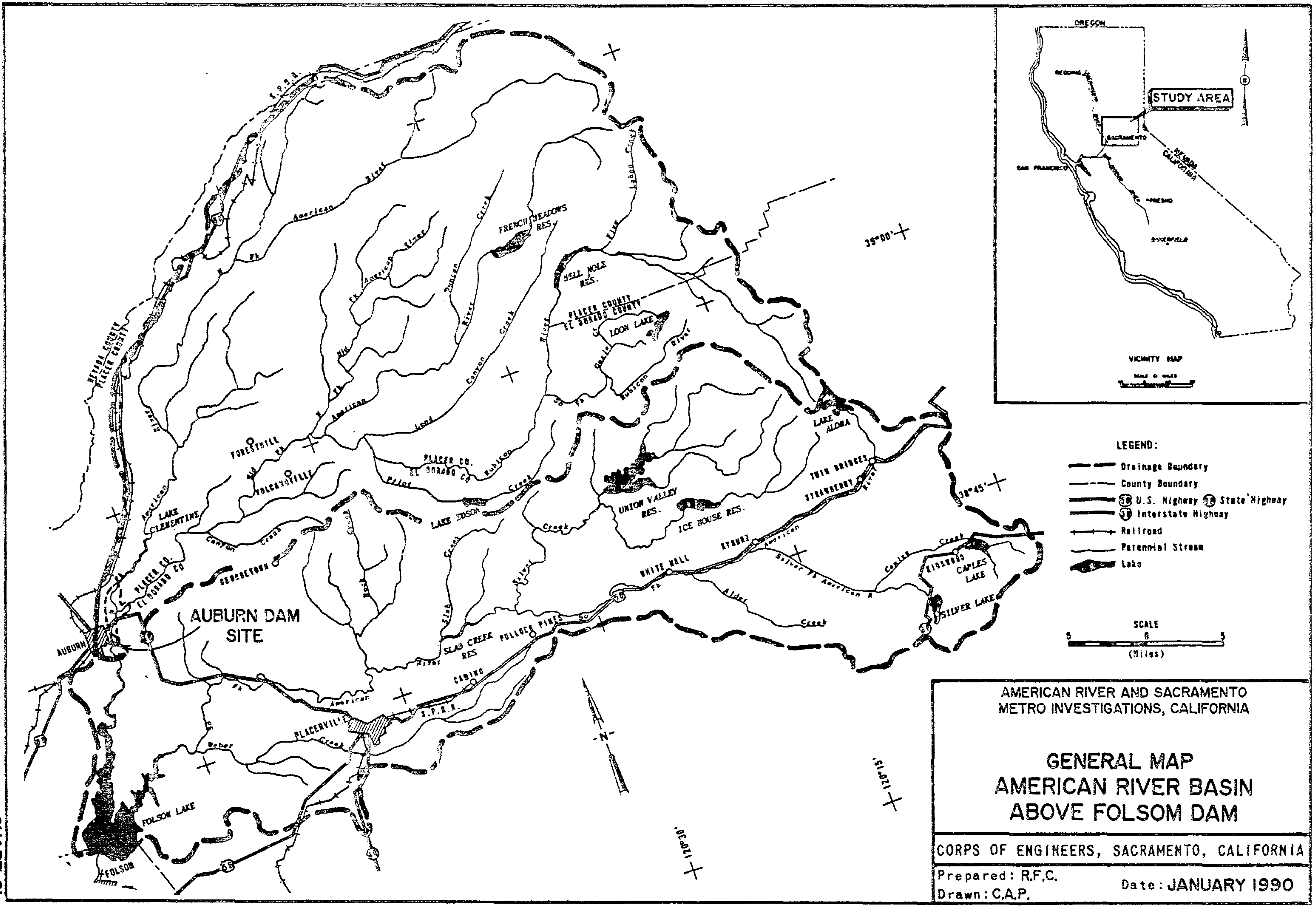
DESIGN PROFILE COMPARISON
NATOMAS EAST MAIN DRAIN

CORPS OF ENGINEERS. SACRAMENTO. CALIFORNIA

Prepared : J.H.
Drawn : J.H.

Date : JANUARY 1990

SHEET 2 OF 2 CHART 60



AMERICAN RIVER AND SACRAMENTO
METRO INVESTIGATIONS, CALIFORNIA

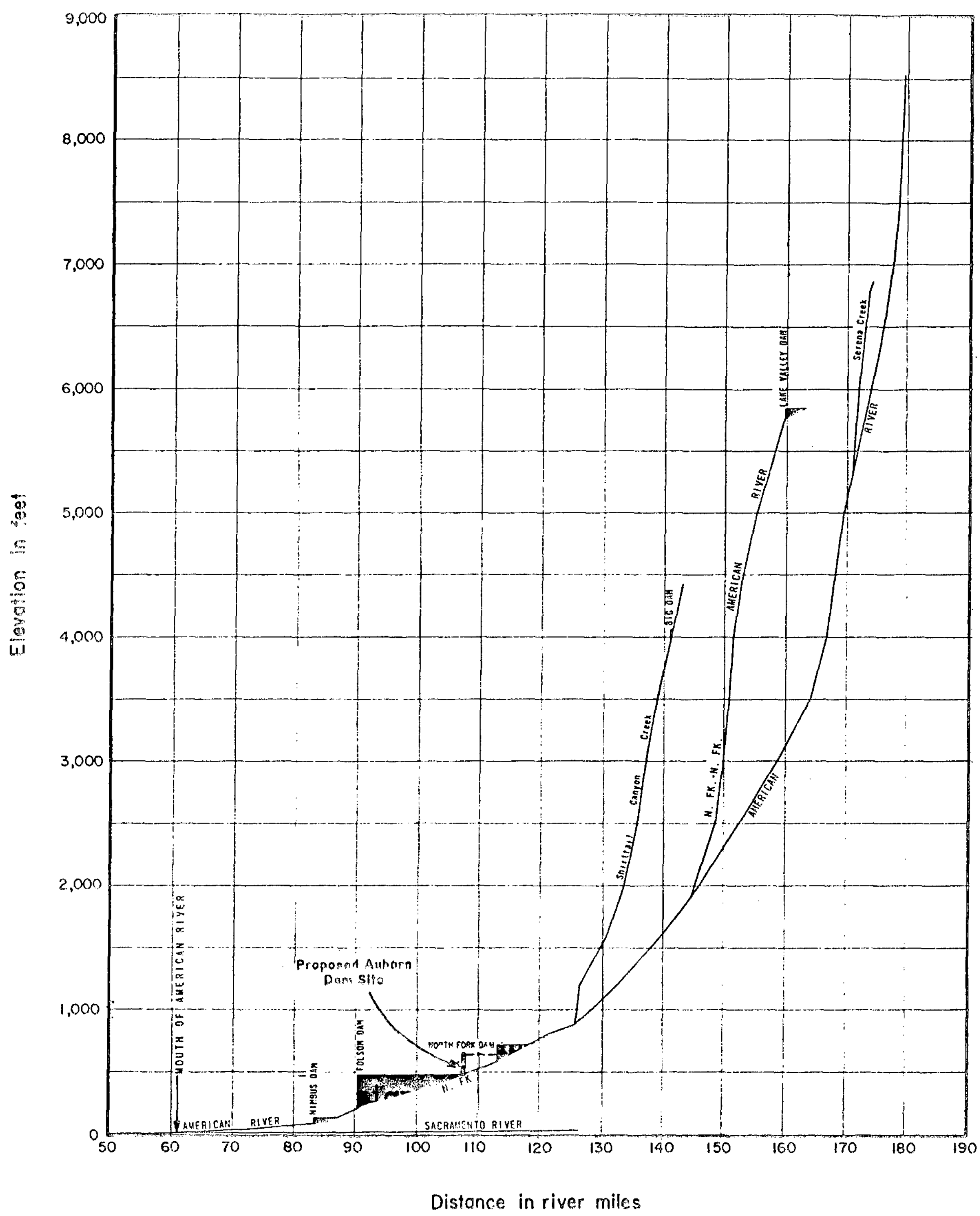
GENERAL MAP
AMERICAN RIVER BASIN
ABOVE FOLSOM DAM

CORPS OF ENGINEERS, SACRAMENTO, CALIFORNIA

Prepared: R.F.C.
Drawn: C.A.P.

Date: JANUARY 1990

CHART 61



NOTE: MILE 0.0 ON SACRAMENTO RIVER AT COLLINSVILLE

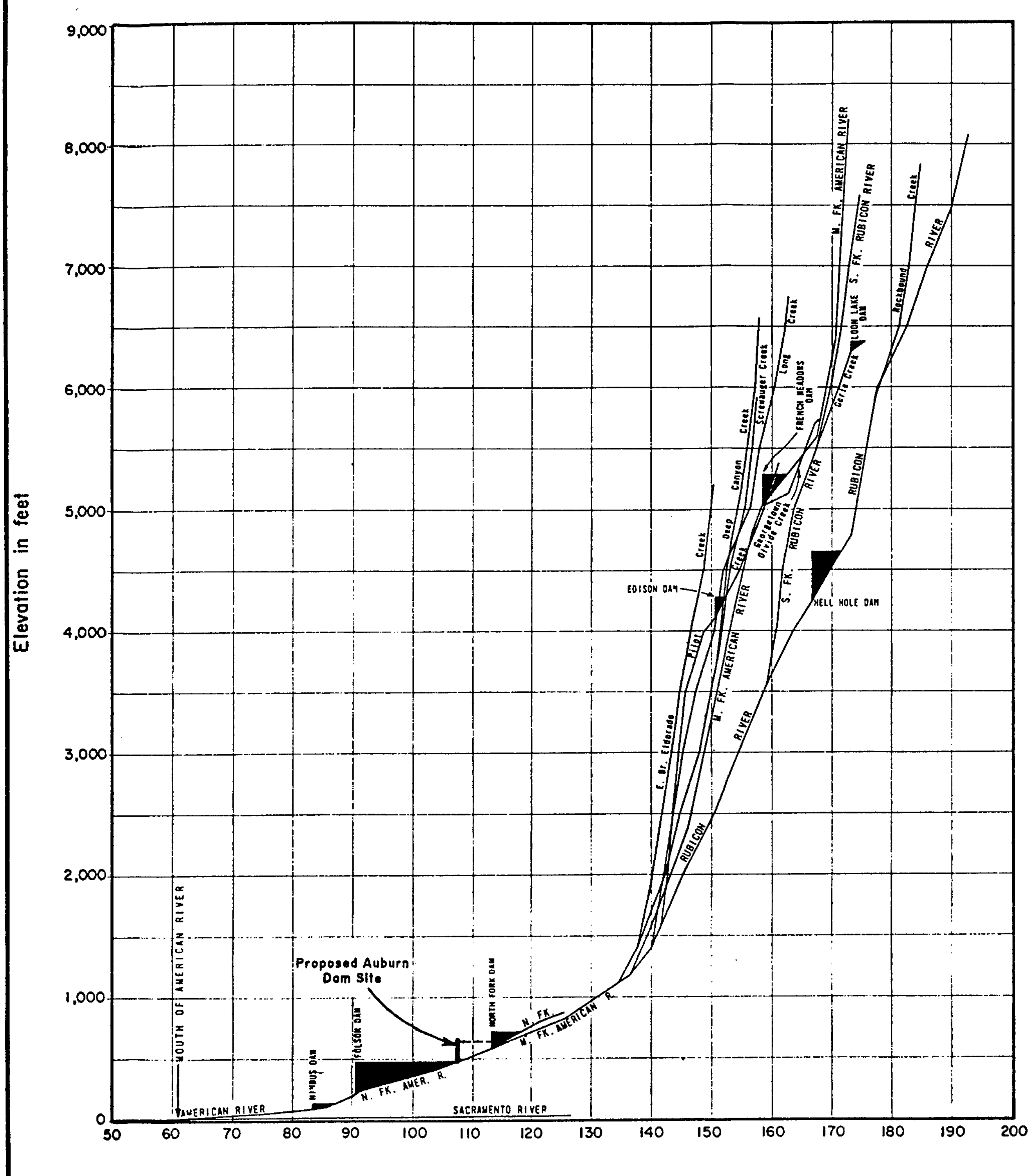
AMERICAN RIVER AND SACRAMENTO
METRO INVESTIGATIONS, CALIFORNIA

STREAM PROFILES
NORTH FORK AMERICAN RIVER

CORPS OF ENGINEERS, SACRAMENTO, CALIFORNIA

Prepared: R.F.C.
Drawn: C.A.P.
Date JANUARY 1990

CHART 62



NOTE: MILE 0.0 ON SACRAMENTO RIVER AT COLLINSVILLE

AMERICAN RIVER AND SACRAMENTO
METRO INVESTIGATIONS, CALIFORNIA

STREAM PROFILES
MIDDLE FORK AMERICAN RIVER

CORPS OF ENGINEERS. SACRAMENTO. CALIFORNIA

Prepared: R.F.C.
Drawn: C.A.P.

Date JANUARY 1990

CHART 63

LEGEND:

- Drainage Boundary
- —5— Contour in 1,000 feet (screened lines)
- —45— MAP Isohyet amount in inches
- ● Recording
- ○ Non-Recording
- ◑ Both Types

-N-

SCALE
5 0 5
(Miles)

PRECIPITATION STATIONS

NO.	DESCRIPTION	NO.	DESCRIPTION
1	+ Tahoe Vista	40	Aerojet
2	+ Tahoe City	41	Represa
3	+ Squaw Valley	42	Folsom Dam
4	+ Donner Mem. St. Park	43	Long Valley Orch.
5	+ Soda Springs 1E	44	Shingle Springs
6	+ Onion Creek	45	El Dorado FFS
7	+ The Cedars	46	Diamond Springs
8	+ Talbot Camp	47	Placerville
9	+ Robertson Flat	48	Placerville 1W
10	+ Big Bend R.S.	49	Coloma
11	+ Westville	50	Garden Valley
12	+ Drum Forebay	51	Greenwood 1SE
13	+ Blue Canyon	52	+ Paradise Valley
14	+ Lake Spaulding	53	+ Applegate
15	+ Fuller Lake	54	+ Foresthill R.S.
16	+ Washington	55	+ Todd Valley
17	+ Deer Cr. P.H.	56	+ Volcanoville
18	+ Washington Ridge Camp	57	+ Georgetown
19	+ Gold Run	58	+ Georgetown R.S.
20	+ Bear R. Head Dam	59	Placerville IFG
21	+ Colfax	60	Mt. Danaher
22	+ Colfax F.S.	61	Camino Driver
23	+ Weimar 1W	62	Sly Park
24	+ Hidden Valley Rch.	63	Pacific House
25	+ Bear R. Rch.	64	Fresh Pond
26	+ Coon Cr.	65	El Dorado P.H.
27	+ Lincoln GENE	66	Jaybird P.H.
28	Newcastle Fowler	67	+ Blodgett Exp. Forest
29	+ KAHI Radio Sta.	68	+ Michigan Bluff
30	+ Cool	69	+ Brushy Spr. G.S.
31	+ Auburn Div. Forestry	70	+ Gerle Creek Camp
32	+ Auburn	71	Union Valley
33	+ Werner Rch.	72	Peavine Ridge
34	Loomis 2NW	73	Wright's Lake
35	Club Rch.	74	Kyburz Strawberry
36	Loomis	75	Twin Lakes
37	Rocklin	76	Meyers 4SW
38	Orangevale Molrae	77	Meyers R.S.
39	Orangevale Beach	78	Meyers Insp. Sta.
		79	D.L. Bliss State Park

\+ Stations shown on this map.

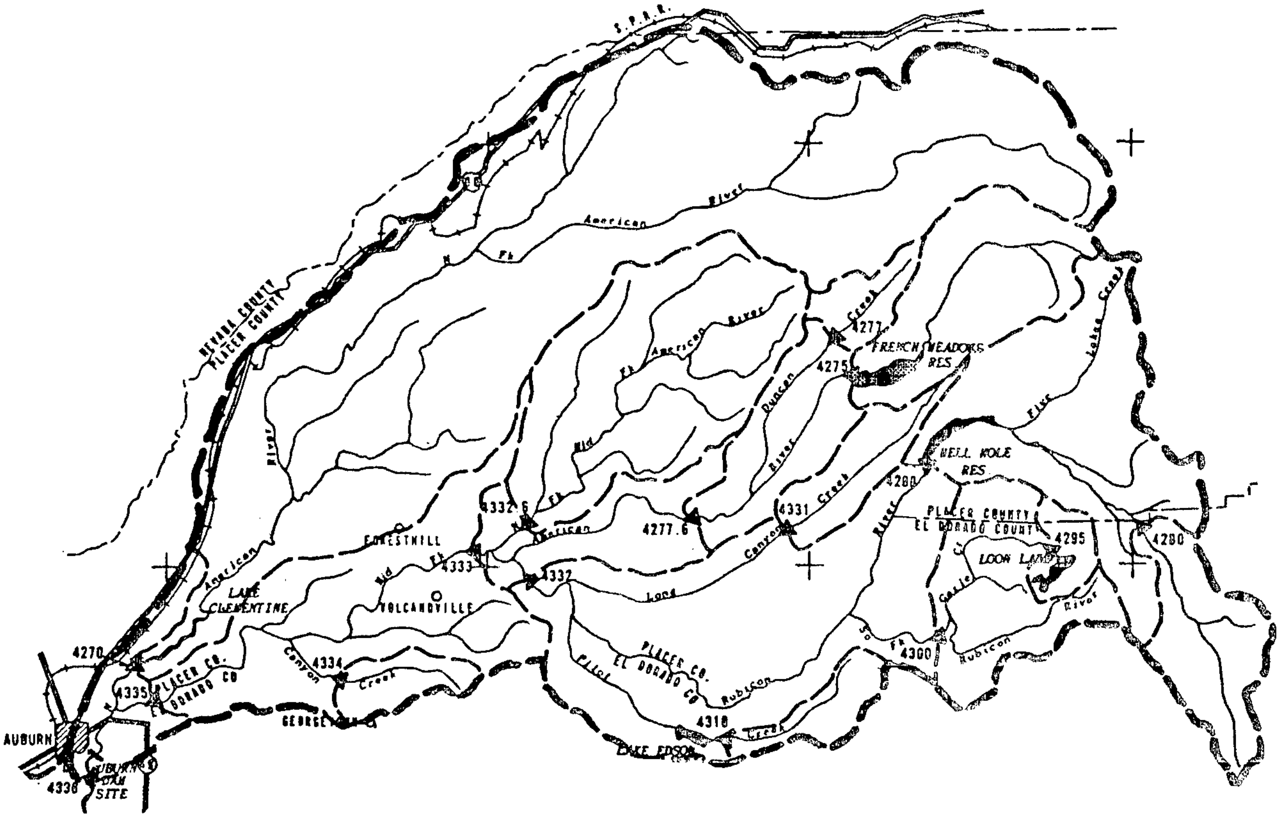
AMERICAN RIVER AND SACRAMENTO
METRO INVESTIGATIONS, CALIFORNIA

TOPOGRAPHIC AND NORMAL ANNUAL PRECIPITATION MAP ABOVE AUBURN DAM

CORPS OF ENGINEERS. SACRAMENTO. CALIFORNIA

Prepared: R.F.C.
Drawn: C.A.P.
Date: JANUARY 1990

CHART 64



STREAM GAGING STATIONS AND SUBAREAS

NUMBER	DESCRIPTION
4270	North Fork American River at North Fork Dam
4275	Middle Fork American River at French Meadows
4277	Duncan Creek near French Meadows
4277.6	Middle Fork American River above Middle Fork Powerhouse near Foresthill
4280	Rubicon River at Rubicon Springs near Meeks Bay
4288	Rubicon River below Hell Hole Dam near Meeks Bay
4295	Gerle Creek below Loon Lake Dam near Meeks Bay
4300	South Fork Rubicon River below Gerle Creek near Georgetown
4318	Pilot Creek above Stumpy Meadows Lake
4331	Long Canyon Creek near French Meadows
4332	Rubicon River near Foresthill
4332.6	North Fork of Middle Fork American River near Foresthill
4333	Middle Fork American River near Foresthill
4334	Canyon Creek near Georgetown
4335	Middle Fork American River near Auburn
4338	North Fork American River below Auburn Damsite near Auburn

LEGEND:

- Drainage Boundary
- County Boundary
- U.S. Highway State Highway
- Interstate Highway
- Railroad
- Perennial Stream
- Lake
- Stream Gage

SCALE
5 0 5
(Miles)

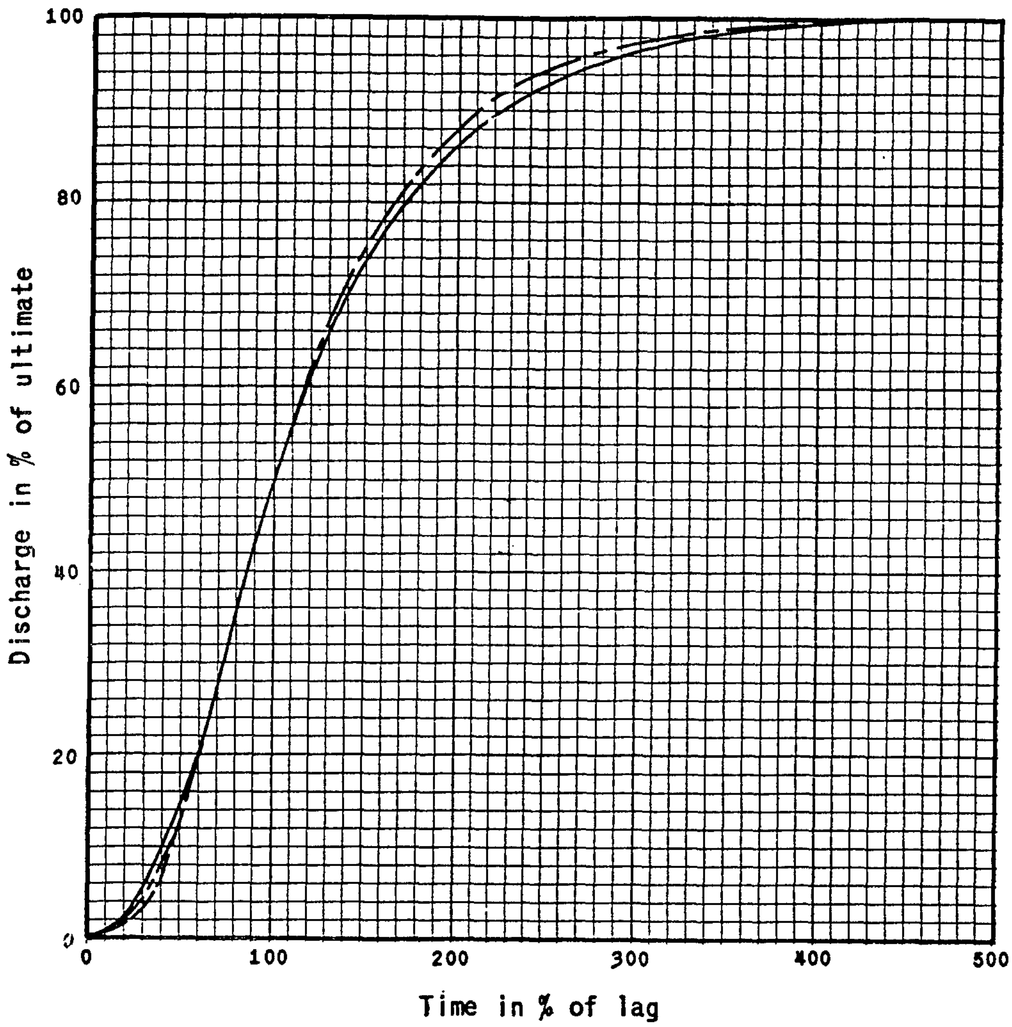
AMERICAN RIVER AND SACRAMENTO
METRO INVESTIGATIONS, CALIFORNIA

SUBAREA MAP
AMERICAN RIVER
ABOVE AUBURN DAM

CORPS OF ENGINEERS, SACRAMENTO, CALIFORNIA

Prepared: R.F.C.
Drawn: C.A.P.
Date: JANUARY 1990

CHART 65



LEGEND

— — — North Fork American River - Length 470.27%
——— Middle Fork American River - Length 460.16%
— - — South Fork American River - Length 420.33%

AMERICAN RIVER AND SACRAMENTO
METRO INVESTIGATIONS, CALIFORNIA

BASIN S-CURVES

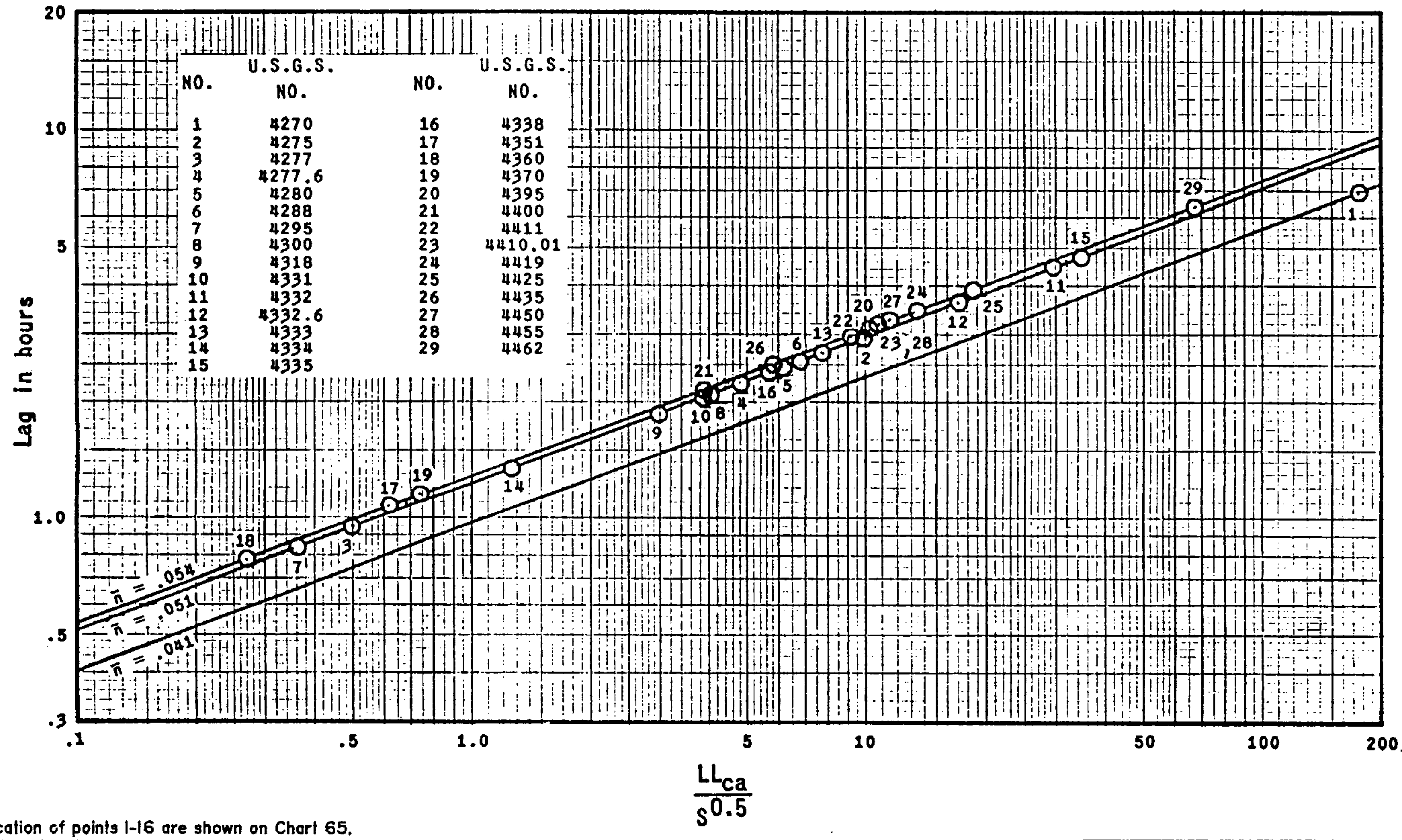
AMERICAN RIVER ABOVE FOLSOM RES.

CORPS OF ENGINEERS, SACRAMENTO, CALIFORNIA

Prepared: R.F.C.
Drawn: C.A.P.

Date: JANUARY 1990

CHART 66



NO.	U.S.G.S. NO.	NO.	U.S.G.S. NO.
1	4270	16	4338
2	4275	17	4351
3	4277	18	4360
4	4277.6	19	4370
5	4280	20	4395
6	4288	21	4400
7	4295	22	4411
8	4300	23	4410.01
9	4318	24	4419
10	4331	25	4425
11	4332	26	4435
12	4332.6	27	4450
13	4333	28	4455
14	4334	29	4462
15	4335		

$$\frac{LL_{ca}}{S^{0.5}}$$

NOTE:

Location of points 1-16 are shown on Chart 65. Points 17-29 are in adjacent basins.

TERMINOLOGY

L - Length of longest watercourse.

L_{ca} - Length along longest watercourse, measured upstream to point opposite center of area.

S - Overall slope of longest watercourse between headwater and collection point.

Lag - Elapsed time from beginning of unit precipitation to instant that summation hydrograph reaches 50% of ultimate discharge.

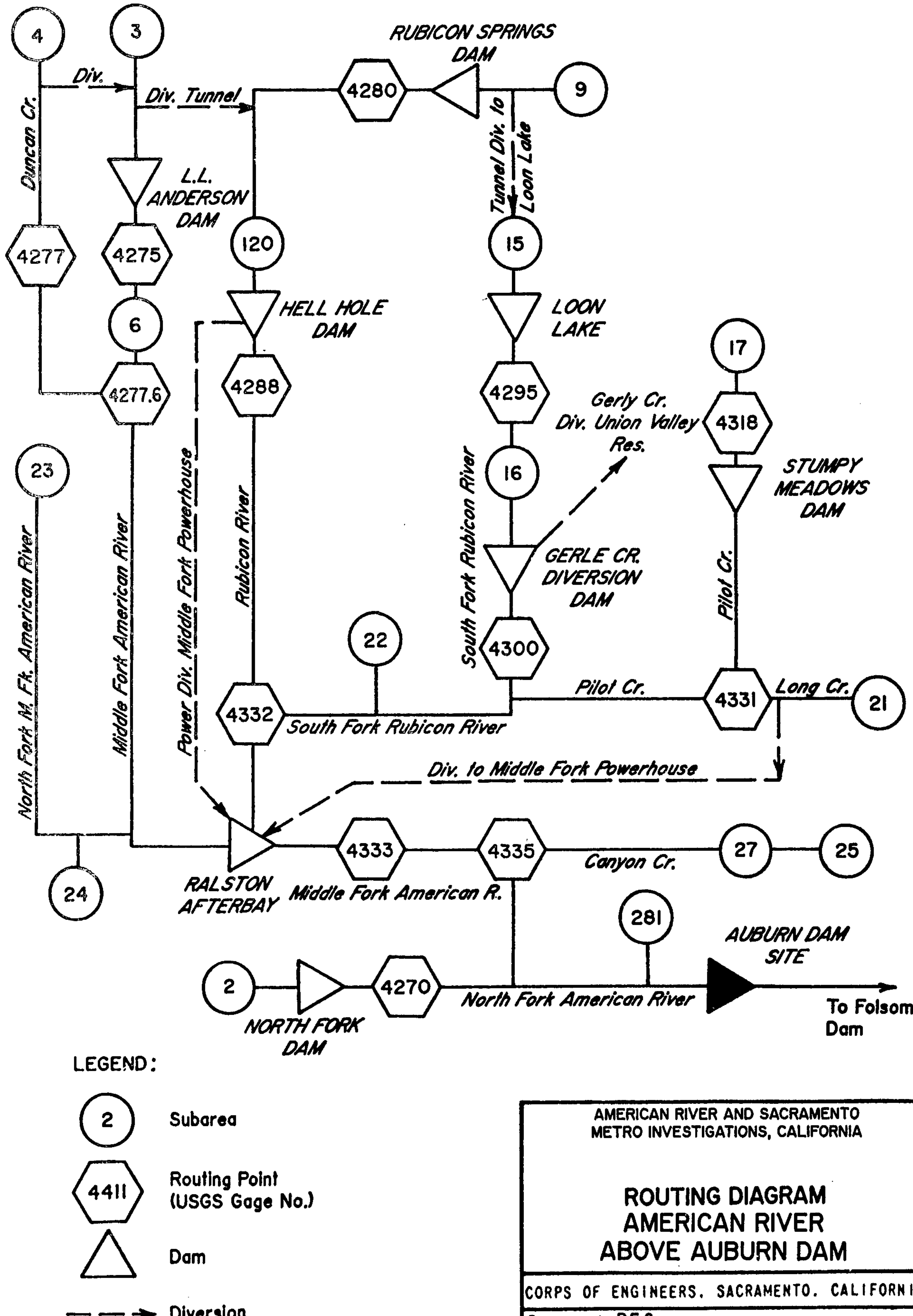
$\bar{n}$ - Basin factor representing basin shape, drainage pattern, and roughness of the stream beds.

AMERICAN RIVER AND SACRAMENTO METRO INVESTIGATIONS, CALIFORNIA

LAG RELATIONSHIPS

CORPS OF ENGINEERS, SACRAMENTO, CALIFORNIA

Prepared: R.F.C.
Drawn: C.A.P.
Date: JANUARY 1990



AMERICAN RIVER AND SACRAMENTO
METRO INVESTIGATIONS, CALIFORNIA

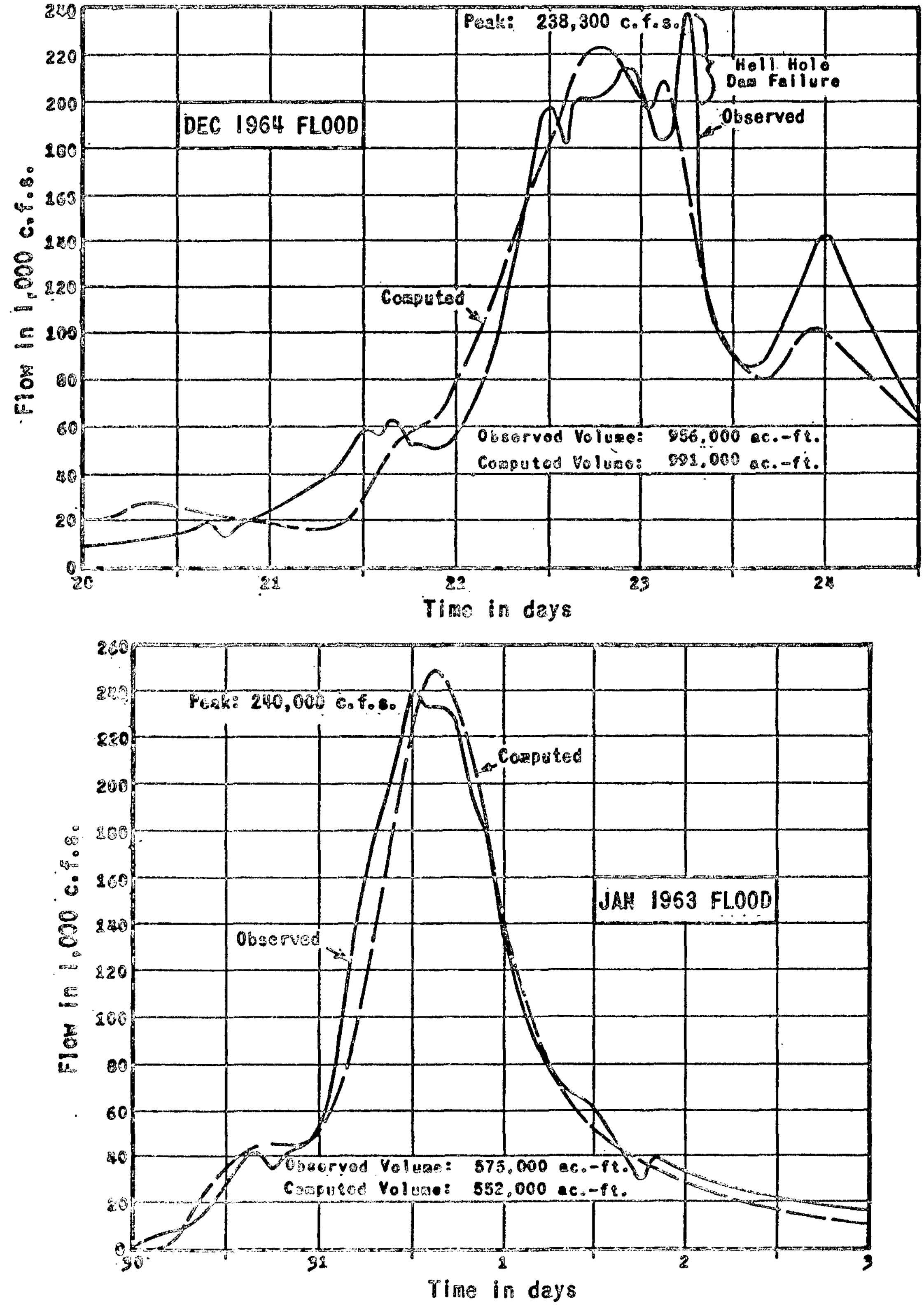
ROUTING DIAGRAM
AMERICAN RIVER
ABOVE AUBURN DAM

CORPS OF ENGINEERS, SACRAMENTO, CALIFORNIA

Prepared: R.F.C.
Drawn: C.A.P.

Date JANUARY 1990

CHART 68



AMERICAN RIVER AND SACRAMENTO
METRO INVESTIGATIONS, CALIFORNIA

FLOOD HYDROGRAPH
REPRODUCTIONS

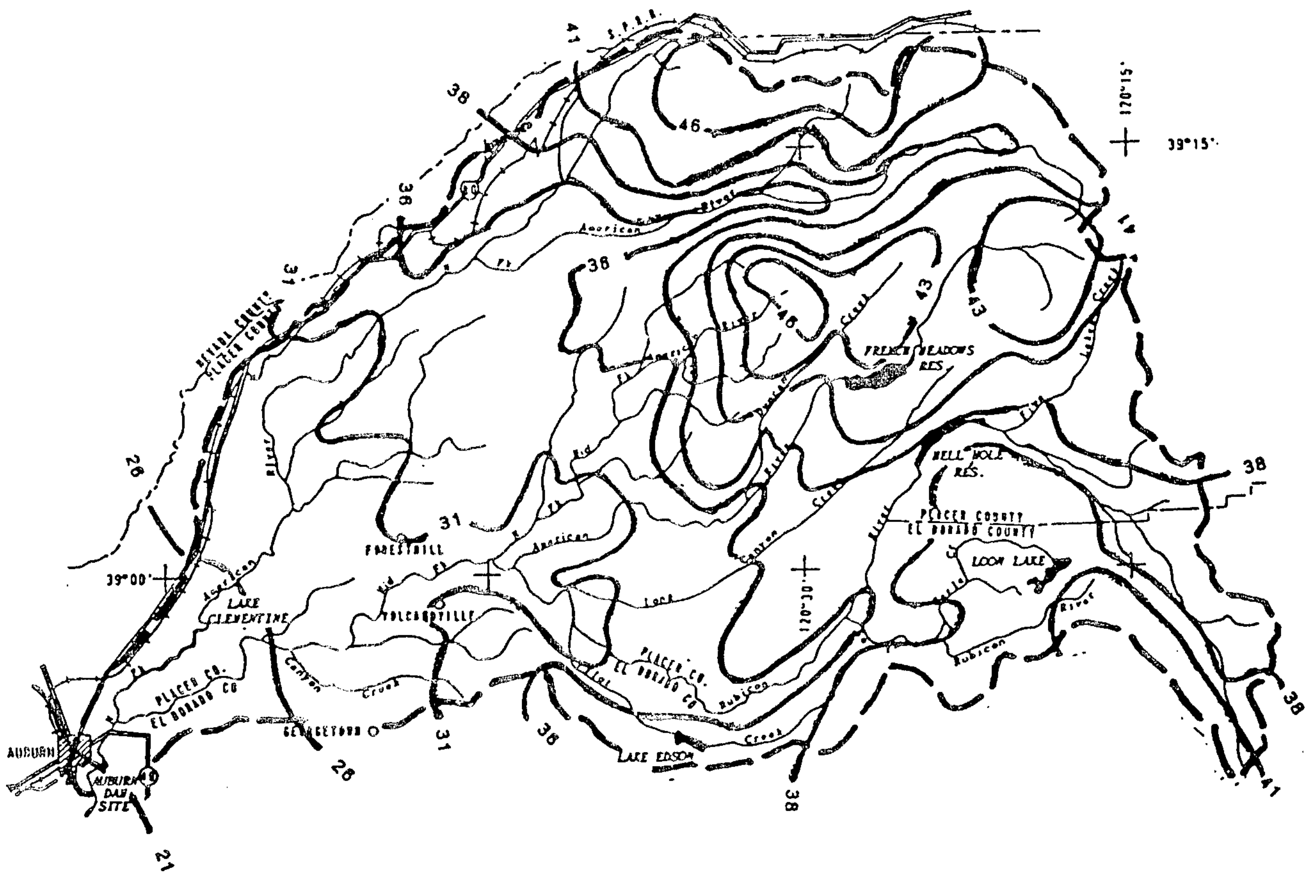
INFLOW TO FOLSOM DAM

CORPS OF ENGINEERS, SACRAMENTO, CALIFORNIA

Prepared: R.F.C.
Drawn: C.A.P.

Date: JANUARY 1990

CHART 69



LEGEND:

Drainage Boundary

County Boundary

U.S. Highway State Highway

Interstate Highway

Railroad

Perennial Stream

Lake

—20— PMP Isohyet amount in inches for 72 hour storm

SCALE

5 0 5

(Miles)

NOTE:

Indices based on U.S. Weather Bureau, Hydrometeorological Report No. 36, October 1961 with revisions of October 1969.

AMERICAN RIVER AND SACRAMENTO METRO INVESTIGATIONS, CALIFORNIA

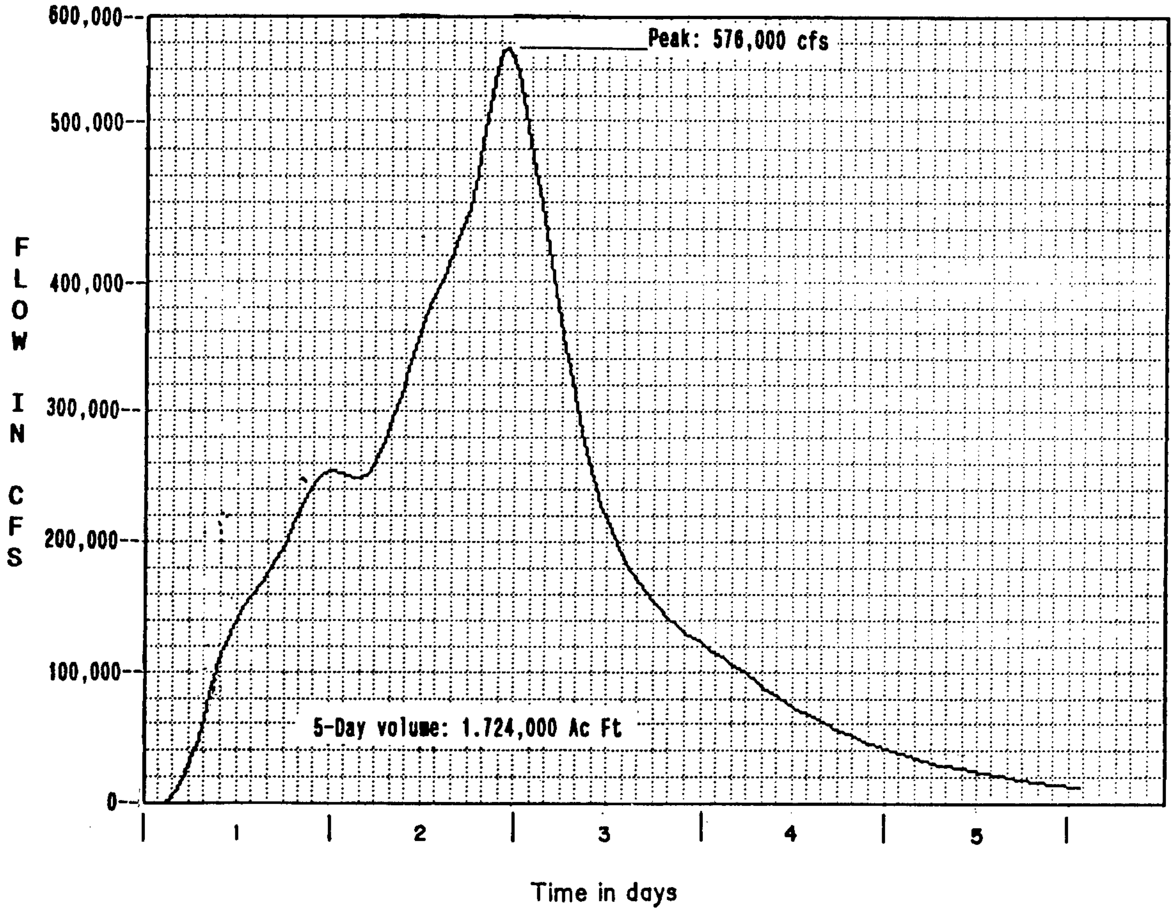
PROBABLE MAXIMUM PRECIPITATION MAP AMERICAN RIVER ABOVE AUBURN DAM

CORPS OF ENGINEERS. SACRAMENTO. CALIFORNIA

Prepared: R.F.C.
Drawn: C.A.P.

Date JANUARY 1990

CHART 70



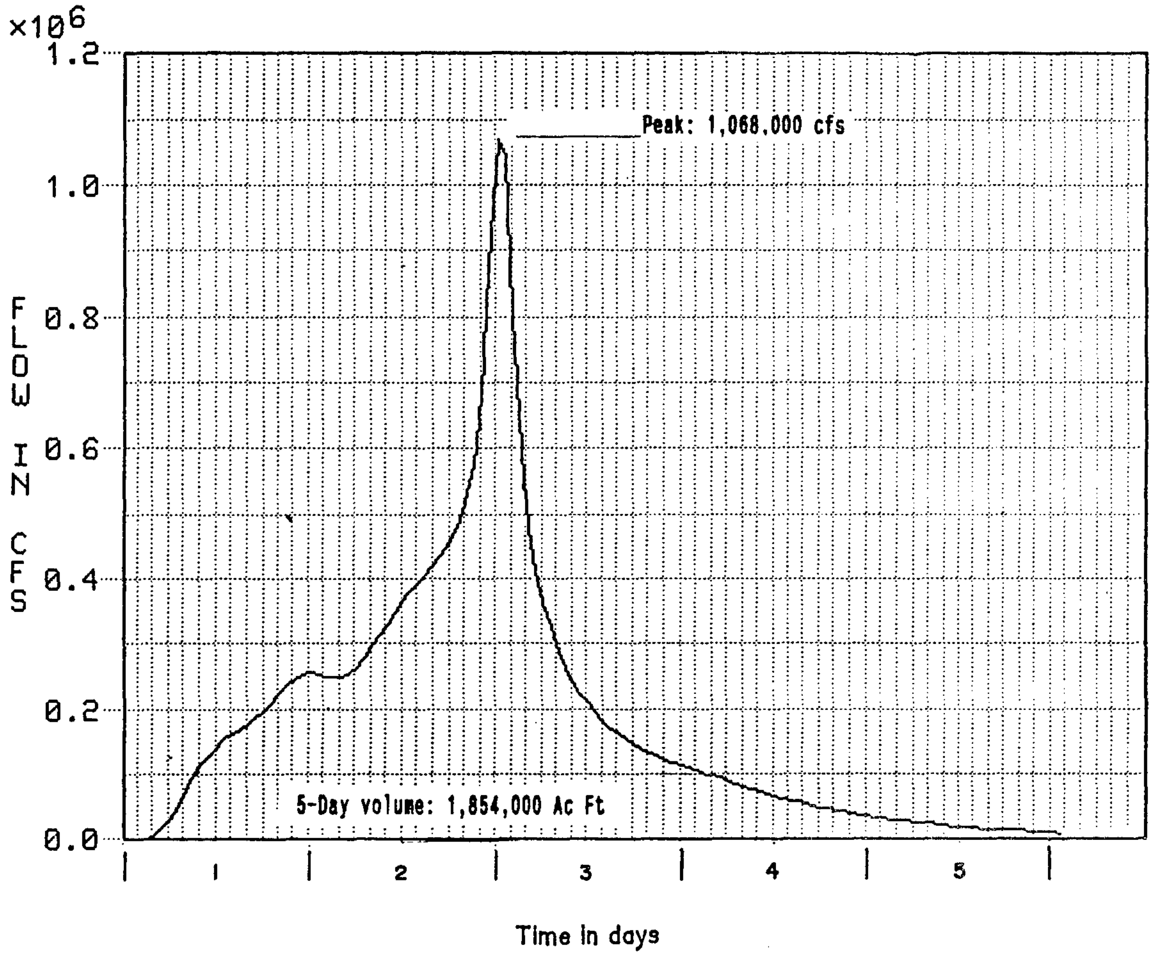
AMERICAN RIVER AND SACRAMENTO
METRO INVESTIGATIONS, CALIFORNIA

PROBABLE MAXIMUM FLOOD AUBURN DAM SITE (WITH NO UPSTREAM DAM FAILURES)

CORPS OF ENGINEERS. SACRAMENTO. CALIFORNIA

Prepared: R.F.C.
Drawn: C.A.P.
Date: JANUARY 1990

CHART 71



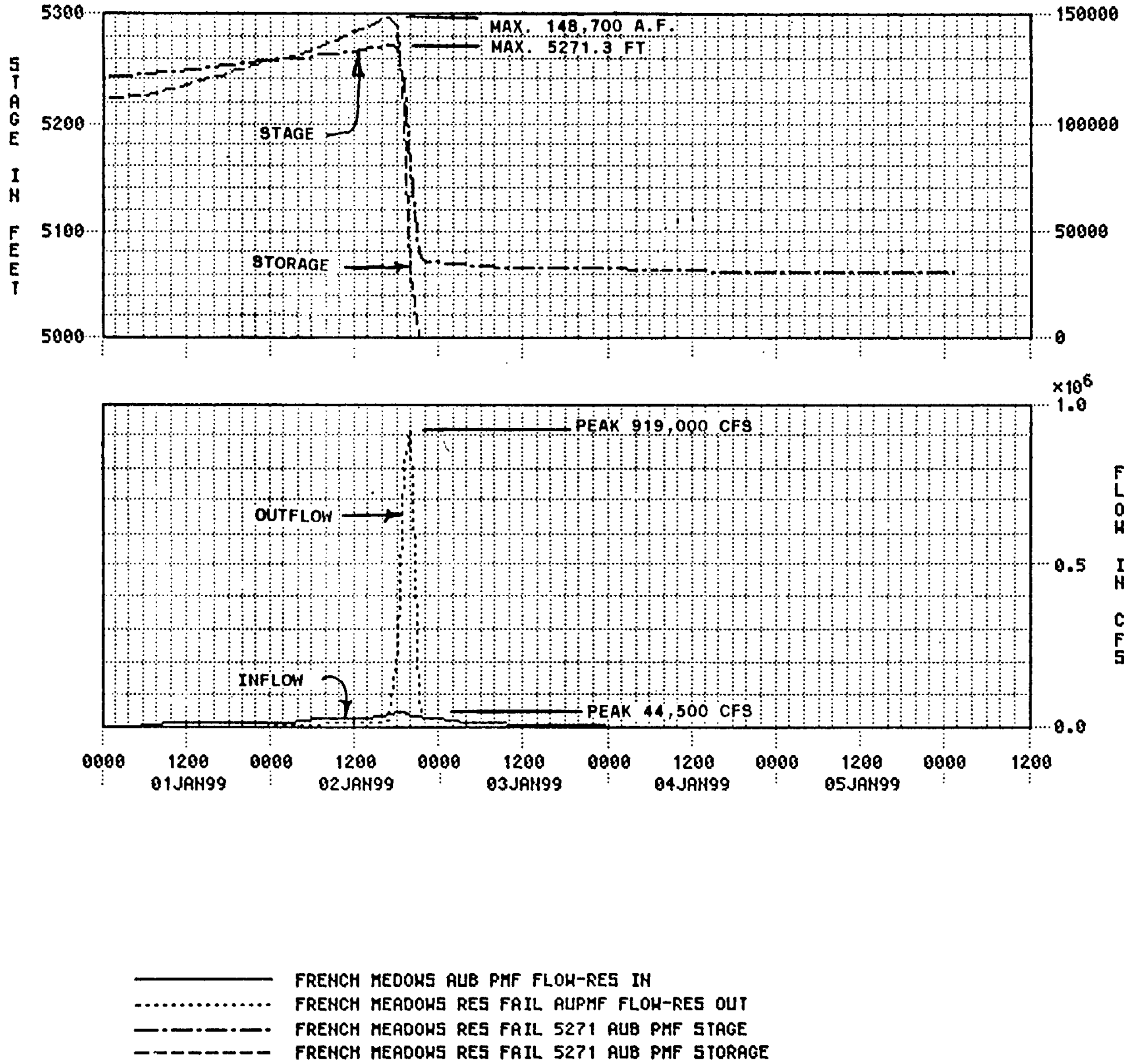
AMERICAN RIVER AND SACRAMENTO
METRO INVESTIGATIONS, CALIFORNIA

PROBABLE MAXIMUM FLOOD
AUBURN DAM SITE
(WITH L. L. ANDERSON
DAM FAILURE)

CORPS OF ENGINEERS. SACRAMENTO. CALIFORNIA

Prepared: R.F.C.
Drawn: C.A.P.
Date JANUARY 1990

CHART 72



AMERICAN RIVER AND SACRAMENTO
METRO INVESTIGATIONS, CALIFORNIA

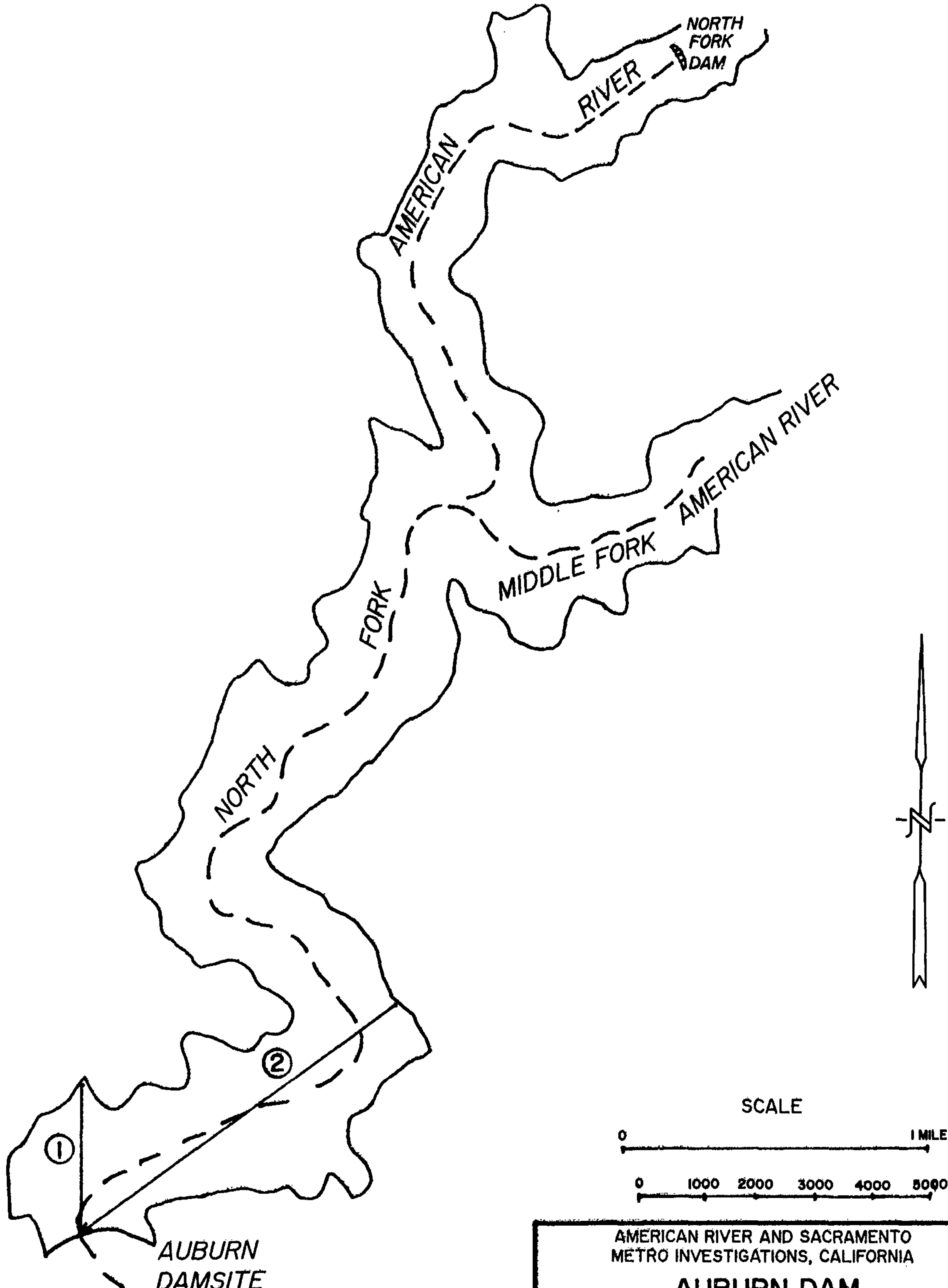
L.L. ANDERSON DAM FAILURE ROUTING

CORPS OF ENGINEERS. SACRAMENTO. CALIFORNIA

Prepared: RFC
Drawn: CAP

Date: JANUARY 1990

CHART 73



200-YEAR POOL ELEVATION
924 FEET MEAN SEA LEVEL

AMERICAN RIVER AND SACRAMENTO
METRO INVESTIGATIONS, CALIFORNIA

AUBURN DAM
WIND-WAVE ANALYSIS
FETCH DIAGRAM
200-YEAR POOL

CORPS OF ENGINEERS. SACRAMENTO. CALIFORNIA

Prepared: J.H.
Drawn: J.H.
Date: JANUARY 1990

CHART 74

American River Watershed Investigation,
California

APPENDIX L

Reservoir Regulation

AMERICAN RIVER WATERSHED INVESTIGATION, CALIFORNIA

APPENDIX L
RESERVOIR REGULATION

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List of Plates

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APPENDIX L
American River Watershed Investigation,
California

RESERVOIR REGULATION
Reservoir Sizing and Flood Operation

INTRODUCTION

Purpose

The purpose of this study is to determine the amount of flood control storage required on the North Fork American River, near Auburn, to provide high levels of protection along the lower American River. Coordinated operations with Folsom Dam were analyzed to optimize the storage requirements. Several dam designs were considered and their affects in the proposed reservoir area were addressed.

Although this analysis is of a structural alternative on the North Fork near Auburn, much of the information developed was used to evaluate the existing flood control system and other alternatives. These evaluations are presented in the main report and other appendices. The history of the basin and description of the study area are also discussed in the main report, Hydrology and other appendices.

Dam Design Alternatives

Flood control routings and dam size optimization studies were performed to provide feasibility scope designs for the following dam alternatives on the North Fork American River, near Auburn, at river mile 20.1 (see Plate 1):

<u>Peak-Flow Detention Dam (Dry Dam)</u> - Single purpose non-expandable, flood control-only dam at the Auburn site capable of providing 100, 200, 250 and 400-year levels of protection, on the lower American River.

<u>Expandable Dam</u> - Single purpose flood control-only dam with base facilities to permit future expansion to a multi-purpose dam.

In addition, reconnaissance level investigations of the following were performed:

<u>Dam Site Comparison</u> - Using existing information from the Bureau of Reclamation and others, a comparison of the river mile 20.1 and 19.0 sites was made for a flood

control-only dam to provide a 200-year level of protection, on the lower American River. Since much is known about the river mile 20.1 site, most of the effort, as described above, will be concentrated there, possibly utilizing the existing diversion tunnel and foundation work at the site.

<u>**Minimum Pool Dam**</u> - This plan consists of an expandable flood control facility with a minimum pool of 127,000 acre-feet for water supply purposes. At this storage, the pool is high enough to supply water by gravity-flow through an existing local water supply tunnel. The dam is to provide a 200-year level of protection on the lower American River.

STUDY APPROACH

An analysis of available flow data was needed to determine the flood potential of the basin. The last statistical analysis of the American River was done in 1961 and included flow data for Water Years 1905-1956. An additional 30 years of record, up to and including 1986, was included in the present analysis.

Flow Frequency Analysis - Unregulated Conditions

Development and analysis of unregulated flows provide a basis for evaluation of the existing system and any alternatives considered, including a structure near Auburn. Unregulated mean daily flow was determined by computing daily reservoir holdouts (change in storage in cfs) then routing and combining them with recorded regulated flows at the Fair Oaks gage, just downstream of Folsom Dam. The reservoir holdouts account for the effects of Folsom Dam and the largest upstream reservoirs including French Meadows, Hell Hole, Loon Lake, Union Valley and Ice House (see Plate 1). The relatively small contributing drainage area between Folsom Dam and Fair Oaks is not significant and therefore no adjustment was made to account for it.

The computed flows updated the previous period of recorded unregulated flow, Water Years 1905-1956, to the long-term records of 1905-1986. This updated streamflow record was used to develop annual maximum volume-frequency relationships at Fair Oaks for durations of 1, 3, 5, 7, 10, 15 and 30-days. The adopted statistics were developed in conformance with the guidelines presented in Reference c. Computed statistics for the analytical frequency curves were adjusted to provide a smooth family of curves. The unregulated rain flood frequency curves are shown on Plate 2. The flow-frequency relationships and other information are further discussed in References a and b, and in the Hydrology Appendix, pages K-11 and K-12.

Subsequent to the above frequency analysis, the flow data for Water Year 1986 used to develop the unregulated frequency curves has changed. The 1986 flow and storage data obtained to compute the curves presented on Plate 2 were preliminary (data provided on worksheets, not published). This data did vary from that subsequently published. In addition, the annual maximum 1-day mean flow for 1986 is in error. The flow was not adjusted to account for the effects of the Auburn cofferdam. The 1986 mean 1-day flow was reduced from about 204,000 cfs to 171,000 cfs (plotting position dropped from the highest to the third highest). However, the cofferdam did not affect the longer durations since it filled and breached in less than three days.

A statistical analysis was performed using the revised 1986 data for the period of record from 1905 through 1986. The effect was a slight lowering of the mean 1-day frequency curve (i.e., the mean 1-day flow volume for the 100- and 200-year recurrence intervals were reduced by about five percent). The frequency curves for all other durations did not change. As a result, the designs presented in this report are not affected. The critical three through ten day flow volumes are unchanged.

An additional statistical analysis was done which included Water Years 1905 through 1991. The computed statistical means for all durations were reduced due to the addition of the relatively dry water years of 1987 through 1991. However, the generally higher standard deviations, and more positive skews, generated frequency curves very similar to those presented on Plate 2.

Based on this updated information, any change to the flow data developed and used as a basis for the designs presented in this report is unwarranted.

Levels of Protection

The levels of protection pertain to flows in the lower American River at the Fair Oaks gage, downstream of Folsom Dam, and include the 100, 200, 250, and 400-year levels. The shape of the hypothetical inflow hydrograph was derived from a balanced 200-year flood, unregulated conditions, see Plate 3. The hydrograph was patterned after the Probable Maximum Flood (PMF) developed in 1980 to evaluate the adequacy of the Folsom Spillway. The flow volume-frequency-duration relationships of the rain flood frequency curves, see Plate 2, were used to develop the 200-year balanced hydrograph. Inflow hydrographs for other exceedence intervals (100-year, 400-year, etc.) were derived the same way.

For analysis at the Auburn dam site, sixty-seven percent of each inflow hydrograph ordinate was used to represent the flow at the Auburn dam site, while the remaining thirty-three percent represents the contributing area below Auburn, which includes the South Fork American River. This ratio is based on a Normal Annual Precipitation (NAP) and drainage area relationship and is supported, on average, by historic flood flow data. The ratio has varied by as much as ±5% for large floods. During major flood events, the travel time in the routing reach from the Auburn dam site to Folsom is extremely short, on the order of two to three hours. Velocities are high and Folsom Lake inundates the canyon within several miles of the site. For these reasons, the influence of the routing reach is relatively small.

CONTINGENCIES AND OPERATING CRITERIA

Prior to formulation of any designs, contingencies and reservoir operating guidelines must be determined.

Folsom Dam Operational Contingencies

In planning new projects, the Corps has found it necessary to use an operational contingency (i.e. a factor of operational safety). This contingency is to accommodate numerous conditions such as prior storms, structural problems in downstream channels, potential channel instability, and delays in the initiation of flood releases for a variety of reasons.

During the design phase of Folsom Dam and other projects, the Corps has used eighty percent of the downstream channel capacity for its operating contingencies. However, because of a 35 year operating record for Folsom Dam and Lake, and since the full design channel capacity of 115,000 cfs has been reached during the 1964 and 1986 floods, the operational contingency used in this study was an encroachment of up to 80,000 acre-feet in the flood control space, and an initial flood release of 20,000 cfs.

The contingencies for starting storage and outflow were arrived at by tabulating storages when flood control releases equal to or greater than 20,000 cfs were made. Damages in the channel below Folsom begin at 20,000 cfs. On the average, during these major flood events, Folsom storage was encroached 80,000 acre-feet into the flood control space.

The storage encroachment can be due to antecedent flood events, where insufficient time was available to evacuate the space, or due to the limited outlet and spillway capacity of Folsom Dam at low reservoir elevations. Encroachment can also occur because of the complexity of making real-time decisions in the operation of the reservoir, which is reflected in delays in increasing outflows to the design channel capacity downstream. The delays may be prompted by the need to patrol and evacuate people from the parkway, limit damage to the facilities in the parkway, and limit bank erosion and sloughing of the levees which can occur when releases are increased rapidly. Release decisions in actual operations must therefore consider that, although it is desirable to empty the flood control space as fast as possible, it is not desirable to cause downstream flooding until it is certain that reservoir inflows dictate an increase in releases. Also, dam operations are legally constrained in that large releases should not exceed the maximum inflow rates which have recently occurred into the reservoir. Technology does not currently exist to reliably make anticipatory flood releases based on forecasted inflows.

An expanded stream gage network in the upper American River Basin could provide a more timely estimate of the inflows, soon to occur, at Folsom Lake. This could enable flood releases at Folsom to more closely follow inflows. For this study, the effect would be to reduce or, at best, eliminate the encroachment contingency in some circumstances. The effects of elimination of the contingency are discussed later in the Sensitivity Analysis Section. However, although additional stream gages may improve real-time operation, enough uncertainty exists so that project design should not be based on it.

Folsom Dam Release Lag

Folsom Dam flood releases greater than 20,000 cfs were lagged behind system inflow by four hours. System inflow represents total inflow at Folsom without a dam at Auburn. It is estimated, based on actual operation, that four hours is needed to accurately compute inflow and set the spillway gates at Folsom. A dry dam at Auburn would complicate the inflow computation.

In most cases, Folsom releases were either limited by the outlet capacity or by the recommended rate of change of release soon after releases greater than 20,000 cfs were initiated. The rate of change of release (an increase of no more than 15,000 cfs, or decrease of no more than 10,000 cfs per 2-hour period) was instituted to limit bank scour and sloughing caused by rapid fluctuations in flows. The rate of change of release is documented in the Water Control Manual, Reference a.

Folsom Dam Outlet and Spillway Release Scheme

Initial releases were made through the river outlets, four lower and four upper tiers, with 7,000 cfs of the required release made through the powerhouse. Once the spillway crest was reached, the river outlets were gradually closed while the five main spillway gates were gradually opened. From that point on, when possible, only the five main spillway gates, in addition to the 7,000 cfs through the powerhouse, were utilized for all routings. Releases from Folsom Dam were limited to the desired downstream channel capacity. This scheme approximates actual flood operation. Cavitation may be induced when the hooded river outlets, located in the main spillway section, and the main spillway are operated concurrently. The flow over the spillway may also be less than expected for a given gate setting and head, because releases through the river outlets would hinder the free flow of water over the spillway. Pertinent information about outlets, spillway, and other dam features are available in Reference a. Plate 4 includes Folsom Dam outlet and spillway rating curves. The minimum power pool elevation is 327 feet with 7,000 cfs through the powerhouse attainable above elevation 340 feet. The downstream channel capacity of 115,000 cfs cannot be attained until elevation 446 feet, a reservoir pool storage of about 790,000 acre-feet.

Use of Surcharge Storage and the Emergency Spillway

Surcharge storage and the use of the three emergency spillway gates at Folsom were not considered when sizing a dam at Auburn. Surcharge storage is not used during the design phase of a project to reduce the required flood control space below gross pool. It is a contingency for control of floods larger than the reservoir design flood. The emergency spillway at Folsom, left of the main spillway, is intended for use only during extreme flood periods. Because of its configuration and location, erosion along the toe of the dam, the adjacent embankment, and in the stilling basin, is a major concern if the emergency spillway is used for an extended period.

Existing Upstream Storage Space

Numerous non Federal reservoirs exist in the upper American River Basin (see Plate 1); however, none are operated for flood control purposes. To account for possible incidental storage space in these reservoirs, 47,000 acre-feet of effective usable upstream space was determined to be available for floods of exceedence intervals of 100-years or less. This amount of storage space is in excess of the minimum total observed storage available in the five largest existing upstream reservoirs at the beginning of each season's major flood. It is an estimate of dependable space and is based on 21 years of record since all of these reservoirs were completed. The reservoirs considered were French Meadows, Hell Hole, Loon Lake, Union Valley and Ice House. These reservoirs contain approximately ninety percent of all storage available upstream from Folsom, and capture enough flood flows to measurably impact the inflow into Folsom. A discussion of the upstream reservoirs and development of incidental space available are presented in the Plan Formulation and Hydrology Appendices.

The unregulated hypothetical flood hydrographs developed for this study were adjusted to account for the effects of the existing upstream reservoirs. The ordinates of the rising limb of the inflow hydrographs at Folsom were reduced by eighteen percent until the 47,000 acre-feet of upstream storage was exhausted. The upstream reservoirs control fourteen percent of the drainage area which historically generates eighteen percent, on average, of the runoff into Folsom Lake during each seasons largest flood event. For exceedence intervals greater than 100-years, the upstream reservoirs were presumed full. This was deemed reasonable because of the antecedent moisture (wet) conditions which can be expected for rare events of this magnitude. Extreme events generally occur on a saturated basin and essentially all upstream reservoir space is occupied. Also, many of the major upstream reservoirs have, at some time during the last 30 years, been full or near full at least once during the flood season. At the start of each flood season, the spillway gates, where present, remain open for dam safety purposes; thereby allowing the reservoirs to pass inflow relatively soon after the spillway crest has been exceeded.

Once the inflow hydrographs are developed, and the contingencies and reservoir operation criteria are established, the design routings and system analysis can proceed.

DAM SITE COMPARISON

Auburn site comparison routings were performed to develop dry dam designs at river miles 19.0 and 20.1 (present location of diversion tunnel). Elevation-capacity curves for both locations are shown on Plate 5. The designs were to provide a 200-year level of protection with 400,000 acre-feet of flood control storage in Folsom Lake and an objective release of 115,000 cfs. At river mile 20.1, the total storage required to control to the 200-year level is 545,000 acre-feet (gross pool elevation of 869.0 feet, height above stream bed - 379 feet) with a maximum outflow of 89,000 cfs. At river mile 19.0, the total storage required is 544,000 acre-feet (gross pool elevation of 843.5 feet, height above stream bed - 388.5 feet) with a maximum outflow of 88,000 cfs.

Outlet ratings at both sites were based on the existing diversion tunnel at Auburn lined to a diameter of 30 feet (see Plate 6). Ratios of the tunnel rating were analyzed to optimize usage of the flood control space at Folsom. In other words, essentially all flood space at Folsom was utilized by adjusting both the flood space and outlet ratings at Auburn. Since no damage centers exist between the Auburn dam site and Folsom Lake, the peak outflow from the dam at Auburn was not a consideration for any of the dry dam designs.

AUBURN DRY DAM DESIGN

Dam Size Optimization

Several Auburn dry dam (flood control-only) designs at river mile 20.1 were developed for selected levels of protection. Three alternative amounts of flood space at Folsom were examined including 400,000, 300,000 and 200,000 acre-feet, with an objective release of 115,000 cfs. Initially, ratios of the existing diversion tunnel lined to a diameter of 30 feet, see preceding paragraph, were utilized for optimizing outlet ratings. Outlets were then designed to approximate those ratings. Outlet configurations consisted of multiple sluice-ways at the bottom of the flood pool, just above stream bed. Table L-1 contains results of the routings.

The 300,000 acre-foot flood control storage space alternative at Folsom provides for more efficient Folsom operation for exceedence intervals between about 150-years to just under 400-years, see Plate 7. The 300,000 acre-foot option requires less total system storage but more storage at Auburn. The 200,000 acre-foot alternative is marginally better for exceedence intervals less than 150-years, and the 400,000 acre-foot alternative is optimum for exceedence intervals of 400-years and greater. The optimum storage, lowest total storage for a given exceedence frequency, occurs when the spillway at Folsom is not restricting the desired releases. As the allocated flood space at Folsom is increased, releasing inflow gets progressively more difficult because the limiting capacity of the spillway at Folsom becomes more severe when the bottom of the flood pool is lowered. This causes a reduction of the flows that can be passed through the system in the early stages of a flood event. Flows that can't be passed early must be stored until after the flood, when outflow exceeds inflow. The spillway restriction is not a factor for either the 200,000 or 300,000 acre-foot flood control space alternatives.

TABLE L-1

AUBURN DRY DAM OPTIMIZATION

	Folsom Flood Control Storage											
	400,000 Acft				300,000 Acft				200,000 Acft			
Exceedence Int (Years)	100	200	250	400	100	200	250	400	100	200	250	400
Auburn Max El (Ft MSL)	784	869	891	942	797	881	905	961	824	911	945	1006
Auburn Max Storage (TAF)	270	545	640	894	303	598	703	998	384	733	910	1282
Total Storage (TAF)	670	945	1040	1294	603	898	1003	1298	584	934	1110	1483
Auburn Max Out (TCFS)	108	89	83	68	98	78	71	55	78	55	47	29
%-Outlet Rating	165	118	107	83	147	102	90	65	111	69	57	33

Another factor which determines the optimum storage involves the response of the operationally ungated dry dam at Auburn, during a given flood. The more flood control storage allocated at Folsom, the greater the outlet capacity allowed at Auburn. This means a smaller dry dam is required. Since the releases from the dry dam cannot be controlled, it also means increased inflow into Folsom (combined dry dam releases and South Fork flows). Folsom must then provide space for a longer period of inflows that exceed the downstream design flow of 115,000 cfs. These excess flows must be stored at Folsom. A lesser allocated flood space alternative at Folsom may therefore be more efficient, for a given exceedence interval.

The routings presented on Plates 8 and 9 illustrate this effect. For the 400,000 acre-foot flood space alternative, the dry dam peaks at about midnight of the third day, but Folsom does not peak until one and one-half days later, see Plate 8. If the dry dam outlets were gated, the outflow could be reduced within 12 hours after the storage peaks. The result at Folsom would be reduced inflows with storage peaking lower and much earlier. The reduction in storage at Folsom, about 20,000 acre-feet, would mean a corresponding reduction in allocated flood space at Folsom and therefore less total space required. For the 300,000 acre-foot flood space alternative, the dry dam storage peaks early on the fourth day only about two hours before the storage at Folsom peaks, see Plate 9. The 300,000 acre-foot alternative is more efficient because the reservoirs are in balance, both storages peak about the same time. For the 400,000 acre-foot alternative, the dry dam flood pool peaks and begins falling before the pool at Folsom.

The opposite occurs when a greater flood control space alternative at Folsom is optimum. This effect is apparent for the 200,000 acre-foot alternative, which is less efficient for exceedence intervals greater than 150-years, see Plate 7. For Folsom Dam to control the combined flows from the South Fork American River and the releases from the ungated outlets at Auburn, the outlet capacity at Auburn must be significantly reduced. Therefore, the total storage required at Auburn is much greater in order to compensate for the relatively small amount of allocated flood space at Folsom. The pool behind the dry dam continues to rise long after the pool at Folsom had peaked and began falling, see reservoir routing on Plate 10. The reservoirs are not balanced. Beyond the exceedence interval at which the lesser Folsom flood space alternative crosses a greater flood space alternative, see Plate 7, the allocated flood space becomes severely limiting. As the magnitude of floods increases, this pattern is repeated for each successively greater flood space alternative at Folsom.

The optimum range of storage combinations for each level of protection is shown on Plate 11. The optimum range is bounded on the left side of each curve by an increase in the storage space needed at Auburn. This is due to the reduced dry dam outlet capacity required for Folsom to control the combined flows from the South Fork American River and the releases from the dry dam. The right side is bounded by the limiting spillway capacity of Folsom at the lower pool elevations. The optimum storage occurs when both reservoirs are in balance (both storages peak at the same time).

Outlet rating curves for the 200 and 400-year dry dams, with 400,000 acre-feet of flood control space at Folsom, are shown on Plate 12. During a 200-year design flood with a dry dam at Auburn, releases from Folsom Dam could be expected to maintain the downstream design flow of 115,000 cfs for a maximum of one week.

Additional Auburn Dry Dam routings (river mile 20.1) were made for several levels of protection with 400,000 acre-feet of flood control storage at Folsom, and a downstream channel capacity of 130,000 cfs (Table L-2). When compared with the current downstream channel capacity below Folsom, the 130,000 cfs objective release reduced storage requirements at Auburn by 49,000 acre-feet for the 100-year level, 60,000 acre-feet for the 200-year level, and 84,000 acre-feet for the 400-year level of protection. However, improvements to the lower American River levee system, and possibly the lower Sacramento River system, would be needed to handle the additional sustained flows if the design channel capacity were to be increased.

TABLE L-2

AUBURN DRY DAM OPTIMIZATION WITH DOWNSTREAM CHANNEL CAPACITY BELOW FOLSOM OF 130,000 CFS

	Folsom Flood Space 400,000 Acft		
Exceedence Interval (Years)	100	200	400
Auburn Max Elevation (Ft MSL)	764	853	927
Auburn Max Storage (1,000 Acft)	221	485	810
Total Storage (1,000 Acft)	621	885	1210
Auburn Max Outflow (1,000 cfs)	124	102	81
%-Outlet (Lined Div Tunnel)	196	139	100

Gating the outlets at Auburn for flood control operation purposes would provide some flexibility in operation, but during the design stage would not appreciably reduce the size of a dry dam at Auburn. Given the operation contingencies described earlier, the outlet ratings developed were optimized for a specific design event, Folsom flood control space, and downstream channel capacity alternative. However, a policy decision to gate the outlets provides the opportunity to add more gated sluices. This allows greater outflows from Auburn, early in an event, giving Folsom Dam the ability for greater releases, when and if required. The Auburn flows can then be reduced as Folsom releases reach channel capacity. The result is a reduction in space required at Auburn at the expense of providing additional gated sluices. The effects of a similar operation, and an estimate of reduction in space that can reasonably be expected, are discussed in succeeding sections on reduced inundation-duration times and multi-purpose dam optimization.

Flow Frequency Analysis - Regulated Conditions

The following paragraphs include a discussion of the regulated flood flow-frequency relationship below Folsom Dam for the existing conditions, and for the dry dam designs at river mile 20.1. The dry dam designs presented provide 100, 200 and 400-year levels of protection. Current authorized flood operation of Folsom Dam was applied for the hypothetical routings (i.e., 400,000 acre-feet of flood control space and downstream channel capacity of 115,000 cfs). Operational contingencies, as previously described, were implemented. However, releases from Folsom Dam were limited to the downstream channel capacity until greater releases were recommended by the Flood Control Diagram, see Plate 13, with the use of the Emergency Spillway Release Diagram (ESRD), see Plate 14. Folsom Lake was surcharged as required. In addition, the three emergency spillway gates were used, if needed.

The ESRD was followed as prescribed in the Water Control Manual (Reference a). The only deviation from the present ESRD was the definition of the inflow parameter for the dry dam alternatives. The total system inflow (inflow without Auburn) was defined as the Folsom inflow parameter. Without this adjustment, the ESRD would grossly underestimate the release until it was too late to prevent overtopping. This was due to the ESRD's inability to adequately account for attenuation of flow into Folsom because of the dry dam at Auburn, and the subsequent rapid rise in inflow soon after spilling occurs at Auburn, for floods in excess of design.

Spillway designs at Auburn were for a roller-compacted concrete dam with piers. When spilling, total outflow at Auburn was a combination of the spillway and flood control outlets.

The results of the hypothetical flood routings are included on Table L-3 and Plate 15, Peak Flow Frequency Curves. The plateaus at 5,000 cfs and 8,000 cfs, see Plate 15, are hydropower releases. The one at 115,000 cfs indicates channel capacity. As shown, Auburn Dam could provide additional benefits beyond the design flood by reducing the peak outflows from Folsom Dam. The added flood control storage at Auburn, and its ability to attenuate peak flows into Folsom, combine to reduce Folsom releases recommended by the ESRD. A dry dam, however, would require Folsom to sustain long periods of high outflows after the pool at Folsom begins to fall, in order to draw on the flood control storage in Folsom while providing space for the uncontrolled releases from Auburn (see routings on Plates 16 and 17). As shown on Plate 15, without a dry dam at Auburn, Folsom outflows would be well in excess of the downstream design flow, during rare flood events. A new ESRD for Folsom, to reflect operation as a system, would be developed should a dry dam at Auburn be constructed.

TABLE L-3

REGULATED FLOW-FREQUENCY
AUBURN DRY DAM DESIGNS

	Exc Int (Yr)	Dam	Peak In (1,000 cfs)	Peak Out (1,000 cfs)	Max Stor TAF	Max Elev (Ft)
100-Year Auburn Dam Gross Pool-270,000 AF Spillway Cr.-784.3 Ft	200	Auburn	296	251	321	803
		Folsom	371	240	1102	474
	250	Auburn	317	285	329	806
		Folsom	421	330	1108	474
	400	Auburn	364	349	342	810
		Folsom	517	500	1118	475
	500	Auburn	388	376	348	812
		Folsom	557	557	1119	475
200-Year Auburn Dam Gross Pool-545,000 AF Spillway Cr.-868.5 Ft	250	Auburn	317	124	576	876
		Folsom	238	145	1061	470
	400	Auburn	364	213	617	886
		Folsom	315	245	1108	474
	500	Auburn	388	264	636	890
		Folsom	390	325	1112	475
	1000	Auburn	464	403	678	900
		Folsom	595	575	1122	476
400-Year Auburn Dam Gross Pool-894,000 AF Spillway Cr.-942.2 Ft	500	Auburn	388	97	931	949
		Folsom	254	138	1056	470
	1000	Auburn	464	206	1003	962
		Folsom	308	285	1115	475

Folsom regulated flows less than channel capacity, for floods smaller than design magnitude, could also be expected to occur less frequently, to some extent, due to the presence of flood storage space at Auburn. For flood operation purposes, the releases at Folsom Dam for all Auburn alternatives were based on following total system inflow as closely as possible up to channel capacity. With upstream storage at Auburn, the inflows into Folsom would be lower, thereby reducing the head available at Folsom. The reduction in outflow at Folsom would be due to the limited outlet capacity at the lower pool elevations, not to any change in project operation. This would be especially evident for small to moderate floods with frequencies of 2 to 50 years.

Use of Emergency Gates at the Proposed Dry Dam

Emergency gates would be installed on the sluices in the dry dam to address safety concerns downstream, predominantly on the lower American River. The gates would be non-operational (They are to remain either fully opened or closed). The following paragraphs describe a potential scenario where the emergency gates would provide a benefit.

The most likely problem is a levee failure or impending failure downstream from Folsom Dam during the waning stages of a very large flood. At this time, lower American River levees would have been withstanding design or near-design flood flows for a day or two; Folsom Lake is nearly full, and unrestricted dry dam discharges near a maximum. If a serious levee problem developed without gates at Auburn, there would be no way to temporarily reduce lower American River flows to enable emergency repairs or even to close a levee break. With gates, Auburn releases could be cut drastically and Folsom re-operated somewhat to reduce flood flows temporarily. The amount and length of the reduction depends on the flood and the design of the dry dam.

A levee break could be visualized near H Street Bridge. The American River has been at the project flood stage of 42.8 feet for a day (115,000 cfs). If a 100-year flood happened in a gated dry dam at Auburn, sized for the 200-year flood (545,000 acre-feet), storage would approach a peak of 380,000 to 400,000 acre-feet and discharge would be about 80,000 cfs. Closing all gates would cause storage to rise and surcharging to occur until spillway overflow reached 50,000 to 60,000 cfs during the receding inflow hydrograph. Reservoir storage would then be about 590,000 acre-feet. The net effect would be to reduce Folsom Lake flood inflow temporarily by about 200,000 acre-feet. This would make it possible to cut Folsom releases in half (slowly so as not to cause added levee slumping) to about 55,000 cfs. The 200,000 acre-feet would enable operation at the reduced flow for about 30 hours, enough time to make an emergency levee repair, if the situation wasn't too severe.

At 55,000 cfs, the American River stage would be lowered by around 5 feet...possibly more if flood runoff from the northern Sacramento Valley was light, which would reduce the backwater effect from the Sacramento River. Since natural ground on the land side of the levee is around six feet below flood stage in this vicinity, the flow reduction should be adequate to enable emergency repairs of a potential levee break.

With occurrence of a 200-year flood in a 200-year dry dam, a similar situation would provide much less slack. The dry dam would be nearly full, about 520,000 acre-feet, still slowly filling and discharging around 88,000 cfs. In this case, the reservoir could be surcharged to around 600,000 acre-feet (elevation 882 feet) before spillway overflows reach about 80,000 cfs. This may leave only 60,000 to 70,000 acre-feet of relief for Folsom Lake. Again, with gradual lowering of Folsom releases, this would allow only about five hours of flow reductions to 55,000 cfs, but could be about fifteen hours at 75,000 cfs. Another way to gain time in the latter scenario is to surcharge some at Folsom Lake, which would yield about five hours more time for two feet of surcharge at 55,000 cfs compared to 115,000 cfs. Obviously, this second design flood scenario doesn't provide the flexibility that a somewhat smaller flood would have.

These hypothetical examples show that the ability to control releases at Auburn, with gates, can add to the public safety margin below Folsom Dam in the event of an unexpected levee problem along the lower American River levees. This is particularly so at flood flows less than design. The additional inundation time in the canyon above the dry dam would be only the length of the flow reduction, probably a day or two.

There are other possible reasons why the ability to control dry dam releases during a flood would be desirable. These include a problem at Folsom Dam, which could range from mechanical problems with gates or outlets, to earthquake damage, and possible evacuation problems (most likely people stranded in the parkway) downstream of Folsom Dam which would inhibit raising Folsom releases to the desired objective flows. Another reason would be to handle storms in excess of basin design flow if they were centered over the South Fork of the American River. Even during non-flood situations, emergency gates could aid in rapidly lowering Folsom Lake levels for needed repairs.

SENSITIVITY ANALYSIS

The following factors were tested to determine the magnitude of their effects on the hypothetical flood routings:

(1) The operational contingencies (80,000 acre-foot

initial flood space encroachment and 4-hour lag on releases);

(2) Variations in storm distribution (change in flow-volume distributions between the North Fork, above Auburn, and the South Fork);

(3) The shape of the inflow hydrographs;

(4) The wave series sequences of the inflow hydrographs; and

(5) Sediment deposition.

Operational Contingencies

The 80,000 acre-foot initial flood space encroachment contingency does have an effect on the results of the hypothetical routings. However, the effect is less than requiring an additional 80,000 acre-feet to the flood space needed to control a given flood. The encroachment means Folsom begins each routing at a higher flood pool elevation. This helps compensate for the limiting effects of the spillway at the lower pool elevations. Its influence varies with allocated flood space at Folsom. Plate 17 contains a sample routing of the 85-year flood (FEMA 100-year), with 400,000 acre-feet of allocated flood space, illustrating the effects of the encroachment contingency. The encroachment enables Folsom to pass an additional 48,000 acre-feet through the system. The result is an increase of 32,000 acre-feet of storage in Folsom, with the encroachment contingency, prior to the initiation of flood releases in excess of channel capacity, as prescribed by the Emergency Spillway Release Diagram. Table L-4 is a summary of routings with and without the contingency.

The additional increment of storage required for a 200-year dry dam at Auburn with the encroachment contingency is small, see Table L-4. The dry dam reduces the rate of rise at Folsom thereby enhancing the effects of the limited spillway capacity. This reduces the influence of the encroachment contingency. Based on several routings, a contingency of eighty percent channel capacity is even more conservative (more storage is required) than the storage encroachment contingency.

The influence of the four-hour lag on releases at Folsom is much less than the encroachment contingency. As shown on Plate 18, Folsom releases are governed by not exceeding inflow, lagged four hours, until just before noon of the first day. Beyond this time and until channel capacity is reached, the recommended rate of change of release, and to a greater extent the spillway capacity, limits the releases. In fact, without a lag on releases (perfect operation), the maximum release for the routings present on Plate 18 would still be 160,000 cfs (without 80,000 acre-feet storage encroachment), and would be reduced only 5,000 cfs to 175,000 cfs (with 80,000 acre-foot storage encroachment). In both cases, the maximum storage would be reduced less than 5,000 acre-feet.

TABLE L-4

SENSITIVITY ANALYSIS
FOLSOM DAM AND LAKE OPERATION CONTINGENCY
(Initial Flood Space Encroachment of 80,000 Acre-Feet)

		WITH CONTINGENCY	WITHOUT CONTINGENCY
85-Year Flood	Max Outflow==> (cfs)	180,000	160,000
100-Year Flood	Max Outflow==> (cfs)	230,000	205,000
200-Year Flood	Max Outflow==> (cfs)	430,000	420,000
Level of Protection	Exceedence Interval==>	63-Year	70-Year
200-Year Flood	Storage Required Dry Dam (acft)==>	545,000	523,000

NOTE: Data in table represent existing conditions at Folsom-- 400,000 acre-feet of flood control space and a downstream channel capacity of 115,000 cfs.

Variation in Storm Distribution

The variation in storm distribution, as defined by a change in flow volumes between the North and South Forks of the American River, would have a moderate affect when based on the small variation (±5%) experienced during large floods of record. Historically, sixty-seven percent of the inflows at Folsom are generated above Auburn. By increasing the flows at Auburn to seventy-two percent (+5%), with a concurrent reduction on the South Fork, some spilling would occur for the dry dam designs presented in Table L-1. However, because of the reduced South Fork flows, storage would be available in Folsom to accommodate the spill. Likewise, decreasing flows at Auburn to sixty-two percent (-5%) would mean increased flows on the South Fork requiring some surcharging at Folsom, with the possibility of recommended releases greater than channel capacity. For example, the 200-year dry dam design with 400,000 acre-feet of flood control space at Folsom, see Table L-1, would surcharge about 50,000 acre-feet at Folsom without required releases exceeding channel capacity.

Shape of the Inflow Hydrographs

Numerous variations of (reasonable) inflow hydrograph shapes are possible. However, flow volumes are more critical than the pattern and peak of the inflow hydrograph when sizing a large flood-flow detention structure, such as the dry dam at Auburn. The flood storage space will attenuate the flows. For example, Plate 19 contains a plot of the balanced 200-year hypothetical inflow hydrograph and the 1986 Flood hydrograph boosted to a 200-year volume, based on 3, 5, 7 and 10-day volumes. Both hydrographs represent unregulated conditions. The 200-year dry dam design with 400,000 acre-feet of flood control space at Folsom, see Table L-1, controlled both floods with some surcharging at Auburn and Folsom for the boosted 1986 Flood, without recommended releases greater than channel capacity. Reservoir inflows above channel capacity are exceeded for approximately the same amount of time during both floods, about one-half day longer for the boosted 1986 Flood. More importantly, the volume of flows above channel capacity are approximately equal. The hydrographs were shifted to emphasize this. Given the same inflow volume and distribution for both floods, once channel capacity is reached, all flows greater than capacity must be stored. The routings show less sensitivity to the shape and peak of the hydrograph than to the volume.

Flood Wave Series

A series of storm fronts typifies the major storm events in the region. Many floods are preceded and/or followed by other storms. Operational studies must therefore not only consider the largest flood event in the series but also the potential for smaller floods infringing on the flood space. The small waves of the 30-day, balanced 200-year hydrograph, shown on Plate 3, could just as well precede the main wave. (To satisfy the balanced hydrograph concept, the sequence of flood waves can vary as long as the volume relationships are preserved.)

Hypothetical reservoir routings of various wave sequences were done to find the most critical scenario. The large wave first in the flood series is more critical at Auburn and Folsom. The outlet capacity of both the dry dam and Folsom Dam is sufficient to pass the smaller waves, and evacuate the storage at Auburn and a significant percentage of the flood control storage at Folsom, prior to any subsequent waves. The opposite is true with the existing upstream reservoirs. A series of small waves could exhaust essentially all of the storage space in these reservoirs, prior to the main wave. Each reservoir is capable of releasing only a few hundred cubic feet per second through the powerhouse to the river. In some cases, backwater effects below the powerhouse inhibit releases being made during a flood event. This happens when the stilling basin below the powerhouse becomes inundated, requiring that operation of the turbines ceases in order to avoid damage to the facilities. Historically, large releases have only occurred when the reservoirs are spilling. Often, this has happened at an undesirable time, such as during the peak flood period. Inter-basin transfer only diverts the water into an adjacent reservoir. In effect, even if 47,000 acre-feet or more space is available in these reservoirs, a series of several small waves of an extreme event could fill this space.

Sediment Inflow

The sediment deposition behind a dry dam at Auburn was estimated to be 26,200 acre-feet during the next 100 years (Reference d). This amount of sediment would not significantly alter the flood control capability of the dry dam design alternatives since most of the sediment would be deposited in the lower reaches of the reservoir area, near the dam, during the more frequent events. The change in the storage-outflow relationship provides for higher outflows earlier, thereby compensating somewhat for the additional storage needed to control the design flood. The sediment deposition reduced the design level of protection by approximately five percent, for the 200-year dry dam.

Sediment would also be flushed through the low level sluices, during rarer events, possibly reducing the rate of projected sediment deposition at Auburn.

Arguably, any or all of the factors described in the previous paragraphs, depending on how they are combined, may be as likely to require more flood space as they are to require less space to control a given flood. Therefore, it is important to determine relative effects, as well as expected occurrence, when developing the scenario for the design routings.

MINIMUM POOL PLAN

The minimum pool plan consists of an expandable dam with a permanent water supply pool of 127,000 acre-feet. The dam is to provide a 200-year level of protection with 400,000 acre-feet of flood control storage space and an objective release of 115,000 cfs at Folsom. The flood control outlets are to be ungated and composed of a series of sluices located just above minimum pool. Gated outlets would also be located at the bottom of minimum pool for emergency draw-down and maintenance.

The higher invert elevation of the flood control outlets (715 feet), and corresponding change in storage-outflow relationship for the minimum pool, means more flood control storage is required for the minimum pool plan than it's equivalent dry dam alternative. In contrast to the dry dam, a significant rise in the pool level of the minimum pool dam must occur before large releases are attained. The minimum pool reservoir would have a total capacity of 706,000 acre-feet (579,000 acre-feet of flood control space at a gross pool elevation of 906 feet) with a maximum outflow of 94,000 cfs, see routing on Plate 20. The total rating curve for the flood control outlets is shown on Plate 21.

DURATION ANALYSIS - DRY DAM AND MINIMUM POOL DESIGNS

Elevation-Duration Analysis

The expected elevations and durations of inundation at the Auburn dam site were evaluated in order to determine slope stability and the possible impacts to vegetation in the reservoir area. Flood routings were performed for a 200 and 400-year dry dam, and a 200-year minimum pool alternative. Each alternative consists of 400,000 acre-feet of flood control space in Folsom and a downstream channel capacity of 115,000 cfs. The elevation-duration analysis is based on routings of the 30-day balanced flood series (hourly flows) and included the 5, 10, 25, 50, 100, 200 and 400-year events. Results are shown on Plates 22 and 23 for the dry dam alternatives, and Plate 24 for the minimum pool dam. Each curve defines the duration of time an elevation is equalled or exceeded.

Because of the large capacity of the ungated flood control outlets, most of the flood control storage is evacuated well within 15 days, even during a 400-year event. This is particularly evident for the dry dam alternatives because of the large outlet capacity and corresponding lack of storage (see Plate 5) this low in the canyon. The dry dam design can achieve high head, and therefore high outflows, sooner than the minimum pool design.

The 400-year dry dam design at Auburn will experience higher levels and longer durations of inundation than the 200-year dry dam design. To control a 400-year flood at Folsom Dam the ungated outlets at Auburn need to be further reduced, thereby requiring more space at Auburn. This reduced outlet capacity would cause longer inundation-durations per elevation than the 200-year design, for any given flood.

Hypothetical Operation - Water Years 1905 to 1986

Hypothetical routings to simulate reservoir operation of the dry dam and minimum pool alternatives, described in the preceding paragraphs, were made to establish elevation-frequency relationships based on estimates of historical flows. Mean daily reservoir inflows were generated for Water Years 1905-1986, period of record, and routed through the reservoirs. The inflows were calculated as follows:

(1) For Water Years 1905 through 1941, sixty-seven percent of the gaged flows at Fair Oaks (see paragraph on Levels of Protection) was used at the Auburn dam site. These flows represent unregulated conditions since diversions were minor and no large reservoirs existed in the American River Basin, until Folsom Lake in 1955.

(2) For Water Year 1942 through January 1986, daily recorded flows on the North and Middle Forks just above Auburn were combined. These gage locations account for over ninety-eight percent of the drainage area above the dam site.

(3) The USGS stream gage on the Middle Fork was inundated by the February 1986 Flood, and not repaired. Therefore, it could not be used in combination with the North Fork gage. Instead, from February 1986 through the rest of Water Year 1986, sixty-seven percent of the unregulated flows at Fair Oaks, adjusted to include the effects of the three main reservoirs above the dam site, represented inflow at Auburn. The reservoirs included French Meadows, Hell Hole and Loon Lake. This approach was taken to eliminate the effects of the Auburn Cofferdam, breached during the flood of February 1986, and to reduce the influence of the diversion tunnel at the Auburn dam site for the remainder of the water year.

Both paragraphs (2) and (3) reflect operation of the existing upstream reservoirs as they came on-line.

Results of the simulations for the dry dam and minimum pool alternatives are shown on Plate 25. The curves depict the percent of time (continuous simulation for the 82-year period of record) that a given elevation is exceeded. The elevation-frequencies represent the total for the 82-year period and therefore may occur on consecutive days or during different years. For example, elevation 730 would be exceeded two percent of the time for the 200-year minimum pool design, or a total of 600 days for the period of record. It should also be noted that the minimum pool dam was assumed to maintain its conservation storage of 127,000 acre-feet throughout the simulation.

Estimated maximum reservoir elevations for the major floods of record, based on the simulated operation of the dry dam and minimum pool designs, are shown in Table L-5.

TABLE L-5

SIMULATED HISTORICAL OPERATION
DRY DAM AND MINIMUM POOL DESIGNS
ESTIMATED MAXIMUM POOL ELEVATIONS
(Feet above mean sea level)

	Maximum Elevations		
	Dry Dam (200-Year)	Dry Dam (400-Year)	Minimum Pool (200-Year)
February 1986	762	802	833
December 1964	737	775	815
December 1955	744	769	814
February 1963	723	750	801

Seasonality of Elevation-Frequency - The elevation-frequency relationships exhibit extreme variations by season. Seasonal relationships for the three alternatives are included on Plates 26 through 28.

Significant rain floods in October are rare and of short duration. In addition, the dry ground conditions at the end of the long summer provides for increased infiltration and therefore reduced runoff.

Based on a rainfall record of over eighty years, about eighty percent of the annual precipitation in the American River Basin occurs from November through March. The peak flood season runs from December through February. Rain floods during this period, typically, are large volume and high peak flow events with durations of less than 15 days. The Auburn dry dam and minimum pool alternatives are peak flow detention structures designed to control these floods.

The risk of experiencing a rain flood near design magnitude from April through September is extremely small, even though May is historically the largest flow month (based on monthly flow data for the 82-year record at Fair Oaks, unregulated conditions). Flood flows during this period are generally snow melt which are characterized by flows of long duration and low peak. These flows can readily pass through the ungated outlets at Auburn with minimal inundation in the reservoir area. For example, the maximum mean 3-day volume experienced from April through September, for the period of record at Fair Oaks, is less than eighteen percent of the maximum experienced during the peak flood season. Summer thunderstorms do occur but are local events which barely affect the main stem flows.

Reduction in Duration Times - Environmental concerns surfaced favoring a reduction in duration times at Auburn. To address this, gated outlets, operational during flood situations, in addition to the required ungated flood control outlets were included for the 200-year dry dam design routings. The rating curve of the additional outlets is shown on Plate 29 (equivalent to 10 - 5 foot by 9 foot sluices). For coordinated operation, the gates remained open until Folsom was able to release channel capacity, as needed, and then closed to limit adding to the flood control pool at Folsom. Soon after the Folsom flood pool began to fall, the gates were operated to evacuate Auburn as fast as possible and still provide a reasonable amount of space in Folsom for subsequent high flows. Folsom operating criteria remained consistent with previous routings (400,000 acre-feet of flood space and 115,000 cfs channel capacity).

The ability to make high releases early and then cut-back allowed Folsom to reach channel capacity sooner, thereby reducing the amount of storage space needed at Auburn. The dry dam was able to control the 200-year flood with 526,000 acre-feet of flood control storage, a reduction of about four percent. The additional outlets also significantly reduced duration times at Auburn (see Plate 30). On average, the more frequent the event, the greater the reduction for a given elevation. However, the reduction in duration may result in the following possible consequences:

(1) Increased sloughing in the reservoir area due to a faster rate of soil de-watering, a result of the rapid fall of the reservoir pool; and

(2) Reduced flood control flexibility at Folsom should any subsequent large flows occur. This may be especially crucial for rare events when the level at Folsom may remain near gross pool for longer periods to compensate for the accelerated draw-down rate at Auburn.

No significant reduction in duration was assumed for floods greater than design magnitude. At that point, flows greater than 115,000 cfs would be required. Downstream flooding and dam safety concerns at Folsom would take precedence, requiring limited releases at Auburn for the duration of the storm.

DAM SIZE OPTIMIZATION - EXPANDABLE DAM DESIGN

Auburn expandable dam designs (flood control-only with the capability to expand for water supply and hydroelectric power generation) at river mile 20.1 were analyzed for several levels of protection. Flood control storages in Folsom of 400,000 and 300,000 acre-feet, and an objective release of 115,000 cfs, were studied. Routings for the first stage of the expandable dam, ungated flood control structure, would be similar to the dry dam. For purposes of comparison, therefore, the dam was assumed to be enlarged to the authorized United States Bureau of Reclamation's 2.3 million acre-foot multi-purpose project. The outlet and submerged spillway rating curves used for the routings were based on those developed for the authorized project. Table L-6 contains the routing results. A sample routing is shown on Plate 31.

As with the dry dam alternative, one operational goal of the expanded dam is to optimize usage of the flood control space in Folsom. However, flood releases through the expanded dam at Auburn would be controlled via gated flood control outlets in the dam, or a gated spillway. Due to this capability, any number of operation schemes could be devised. Therefore, the following assumptions were made in addition to those contingencies mentioned in previous paragraphs:

(1) The initial encroachment contingency, 80,000 acre-feet, was split sixty-seven percent at Auburn and thirty-three percent at Folsom, see previous section on Levels of Protection.

(2) Change of release rates at Auburn were limited to a high but reasonable rate of 20,000 cfs/hr. There are no levees or damage centers between Auburn and Folsom that require a reduced rate of change to limit sloughing or erosion.

(3) Maximum objective release at Auburn was 100,000 cfs. This release was chosen since greater releases probably would not be made early in an event, when it would provide the most benefit by allowing Folsom to achieve channel capacity sooner.

(4) Minimum Auburn release was 20,000 cfs.

(5) Initially, Auburn releases were rapidly increased to 100,000 cfs and held at this flow long enough for the pool level at Folsom to reach the elevation necessary to release 115,000 cfs. A submerged spillway at Auburn would allow for large releases as needed.

(6) Once the channel capacity below Folsom was achieved, releases at Auburn were then based on an "equivalent" reservoir concept of balancing the total flood control space in the tandem reservoir system.

The above constraints limit unrealistic and numerous changes in releases at Auburn, which can occur when attempting to balance flood storage in both reservoirs. Other operation schemes could achieve similar flood control storage results.

From the routing results, it can be shown that for the alternatives that provide 400,000 acre-feet of flood space at Folsom, it would be beneficial for releases to exceed 100,000 cfs early enough to assist Folsom Dam in achieving its objective releases (overcome the spillway limitation). However, excessive outflows at Auburn would cause Folsom Lake to fill beyond what is necessary to release channel capacity. This additional space may be needed to control the South Fork of the American River at some later time during the storm. In effect, the flood control storage in the reservoirs would be unbalanced.

Folsom flood control storages of 300,000 and 400,000 acre-feet were the only options evaluated, although based on the assumptions presented in the previous paragraphs, flood control storage in Folsom less than 200,000 acre-feet could control the 400-year event provided the difference in total flood space needed is transferred to Auburn. For the 100-year design flood, outflows at Auburn greater than 100,000 cfs and/or flood control storage in Folsom less than 300,000 acre-feet would provide more effective use of Folsom space. It should be noted, however, that with upstream storage available at Auburn, flood space at Folsom greater than 400,000 acre-feet would require an increase in total flood space because of the spillway limitations at Folsom; while flood space at Folsom less than 300,000 acre-feet would mean less storage available and therefore less operational flexibility for controlling large floods on the South Fork of the American River.

TABLE L-6

AUBURN EXPANDED (MULTI-PURPOSE) DAM OPTIMIZATION

	Folsom Flood Control Storage							
	400,000 Acft				300,000 Acft			
Exceedence Interval (Yrs)	100	200	250	400	100	200	250	400
Auburn Flood Storage (1,000 Acft)	286	531	632	870	295	598	701	946
Total Flood Storage (1,000 Acft)	686	931	1032	1270	595	898	1001	1246
Auburn Maximum Out (1,000 cfs)	100	100	100	100	100	100	100	100

SUMMARY

To provide high levels of protection on the lower American River, several proposed dam designs near Auburn were evaluated. Reconnaissance (R) and Feasibility (F) scope designs included the following alternatives:

Dam Site Comparison (R)

Comparison of ungated dry dam designs, 200-year level of protection, at river mile 20.1 and 19.0;

Flood Control-Only Dam (F)

Ungated dry dam designs for several levels of protection, river mile 20.1;

Minimum Pool Dam (R)

Ungated expandable flood control facility, river mile 20.1, with a minimum pool of 127,000 acre-feet for water supply purposes; and

Expandable Dam (F)

Ungated dry dam designs, river mile 20.1, with structural features to allow for future expansion to a multi-purpose facility.

Optimization of the total flood control storage (Auburn and Folsom) required is based on current hydrology and includes designs for the 100, 200, 250 and 400-year levels of protection. The anticipated frequency, duration and level of inundation were estimated for several designs of the dry dam and minimum pool alternatives, to evaluate possible impacts in the reservoir area and in the lower American River.

REFERENCES

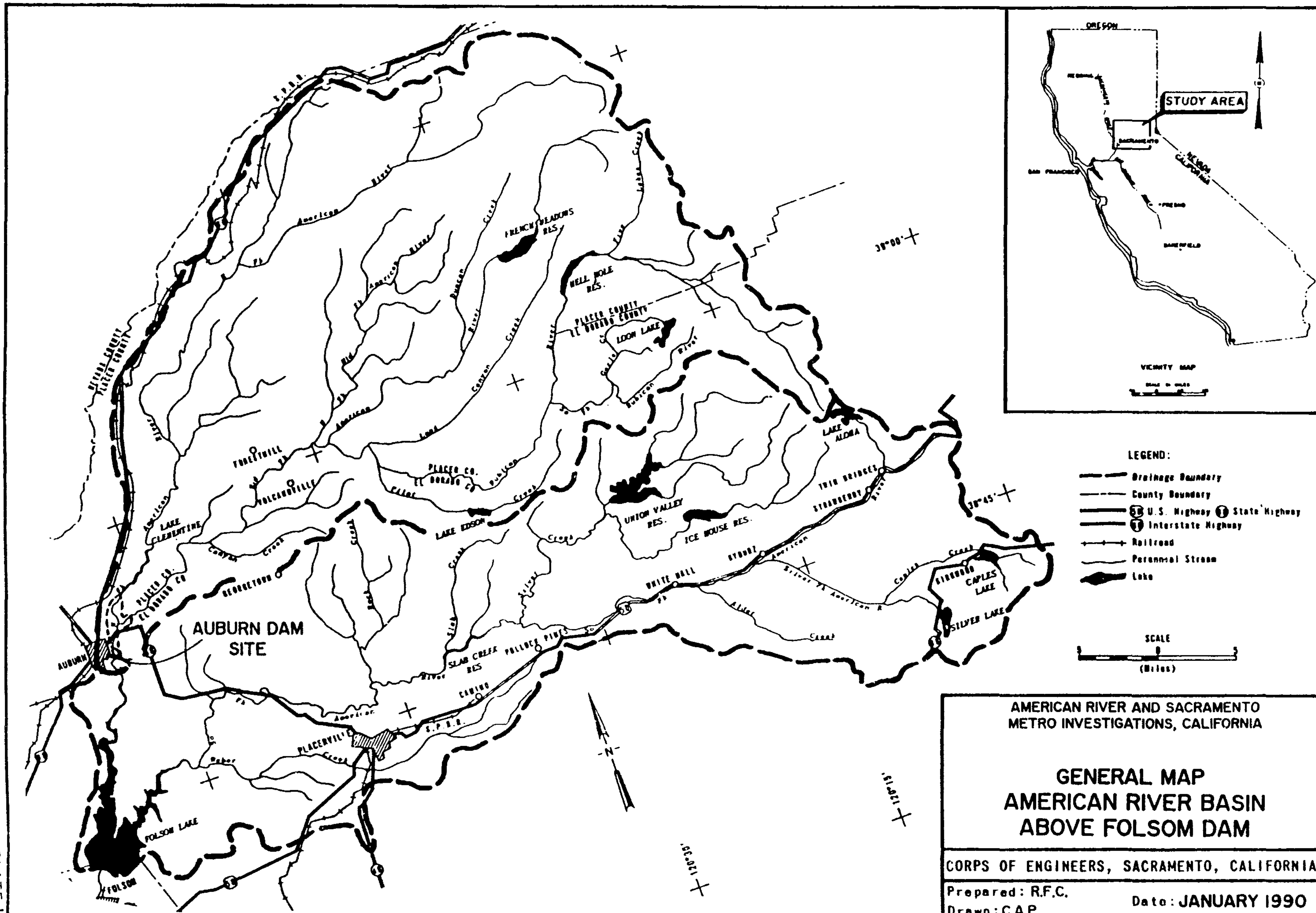
a. Folsom Dam and Lake, American River, California, Water Control Manual, December 1987.

b. Special Study on the Lower American River, California, March 1987.

c. Bulletin #17B, "Guidelines for Determining Flood Flow Frequency", September 1981.

d. HEC-5, Simulation of Flood Control and Conservation Systems Users Manual, May 1988.

e. American River and Sacramento Metro Investigations, California, Hydrology Office Report, January 1990.



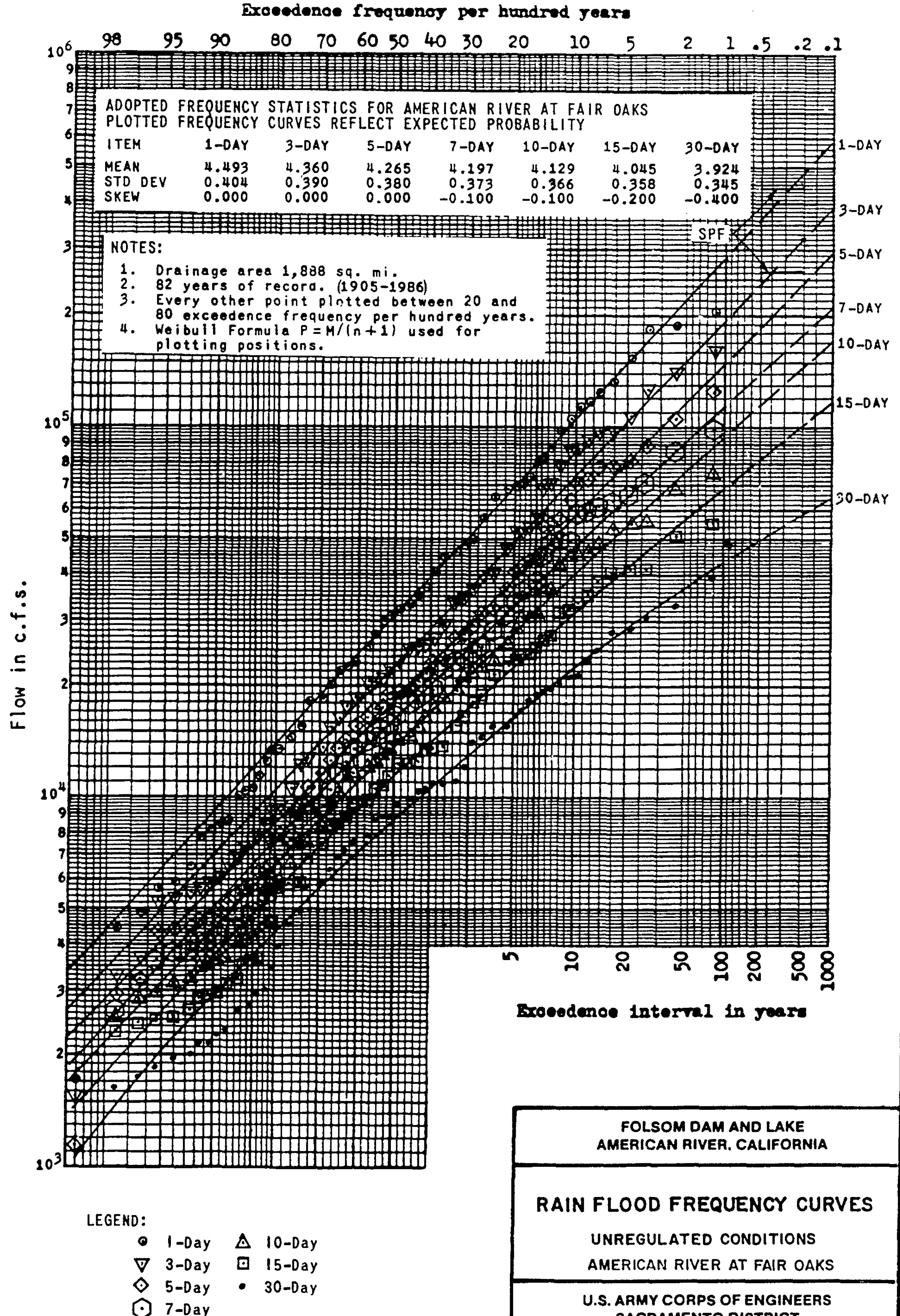
AMERICAN RIVER AND SACRAMENTO
METRO INVESTIGATIONS, CALIFORNIA

GENERAL MAP
AMERICAN RIVER BASIN
ABOVE FOLSOM DAM

CORPS OF ENGINEERS, SACRAMENTO, CALIFORNIA

Prepared: R.F.C.
Drawn: C.A.P.
Date: JANUARY 1990

PLATE I



FOLSOM DAM AND LAKE
AMERICAN RIVER, CALIFORNIA

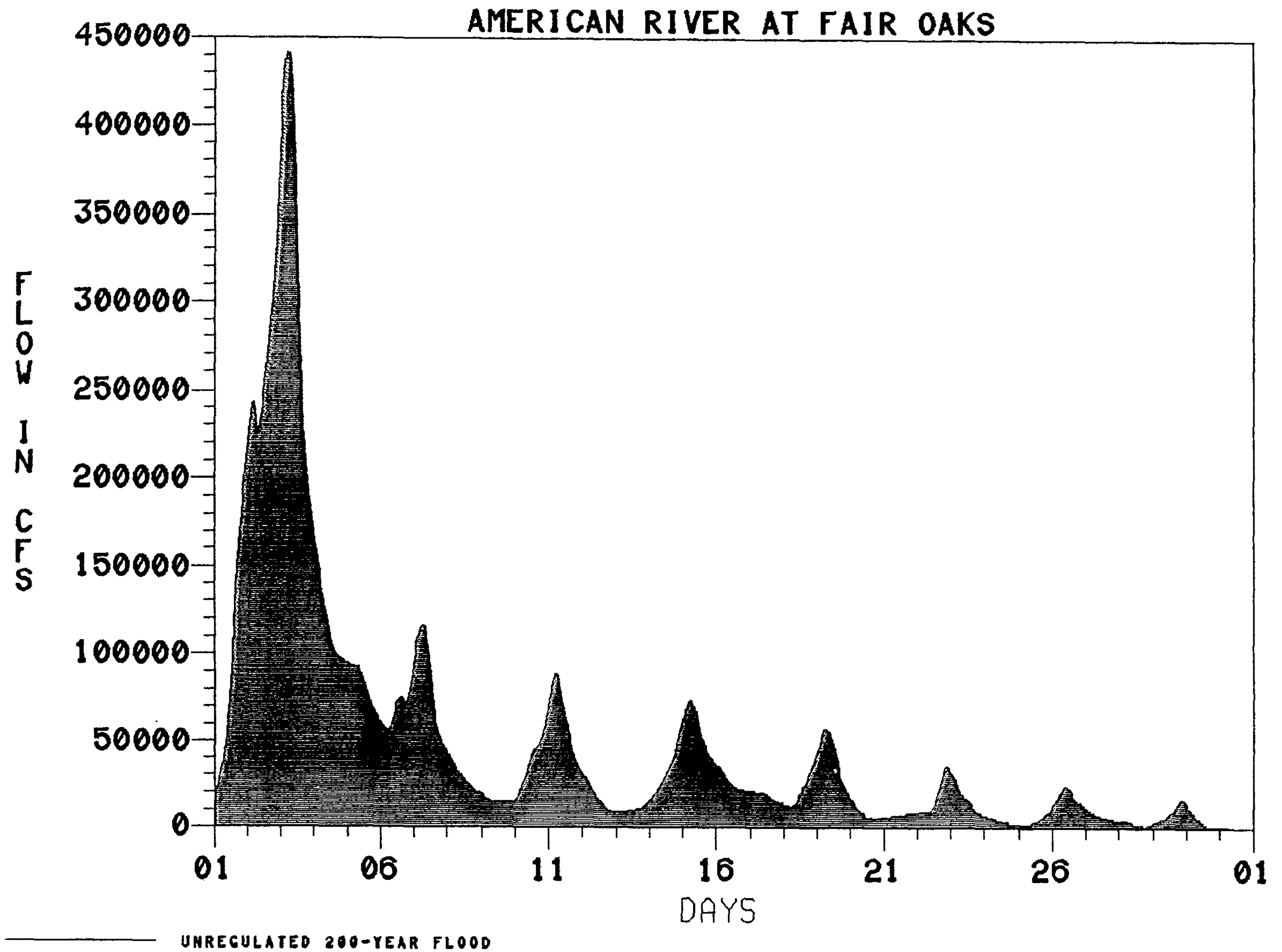
RAIN FLOOD FREQUENCY CURVES

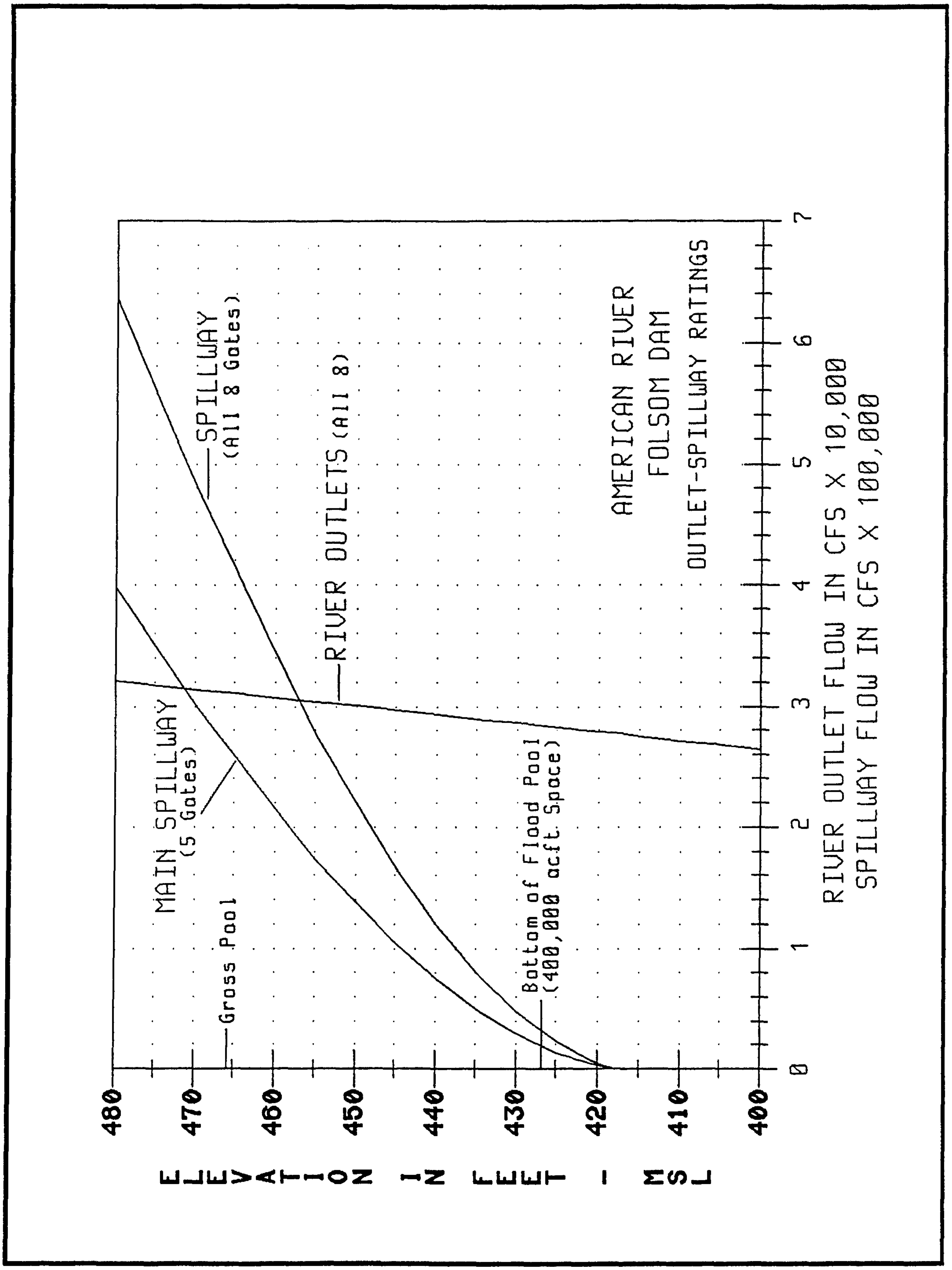
UNREGULATED CONDITIONS

AMERICAN RIVER AT FAIR OAKS

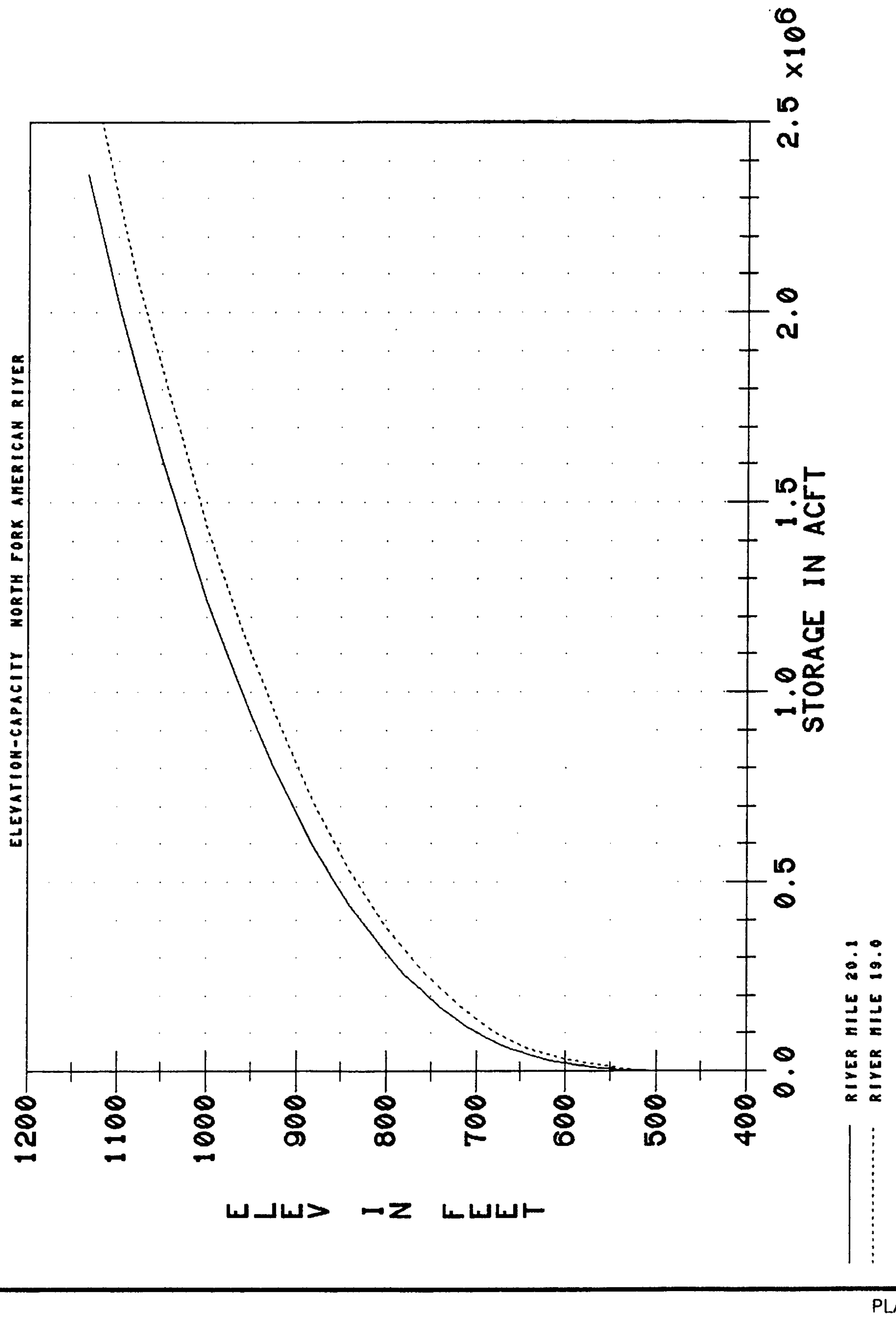
U.S. ARMY CORPS OF ENGINEERS
SACRAMENTO DISTRICT

PLATE 2

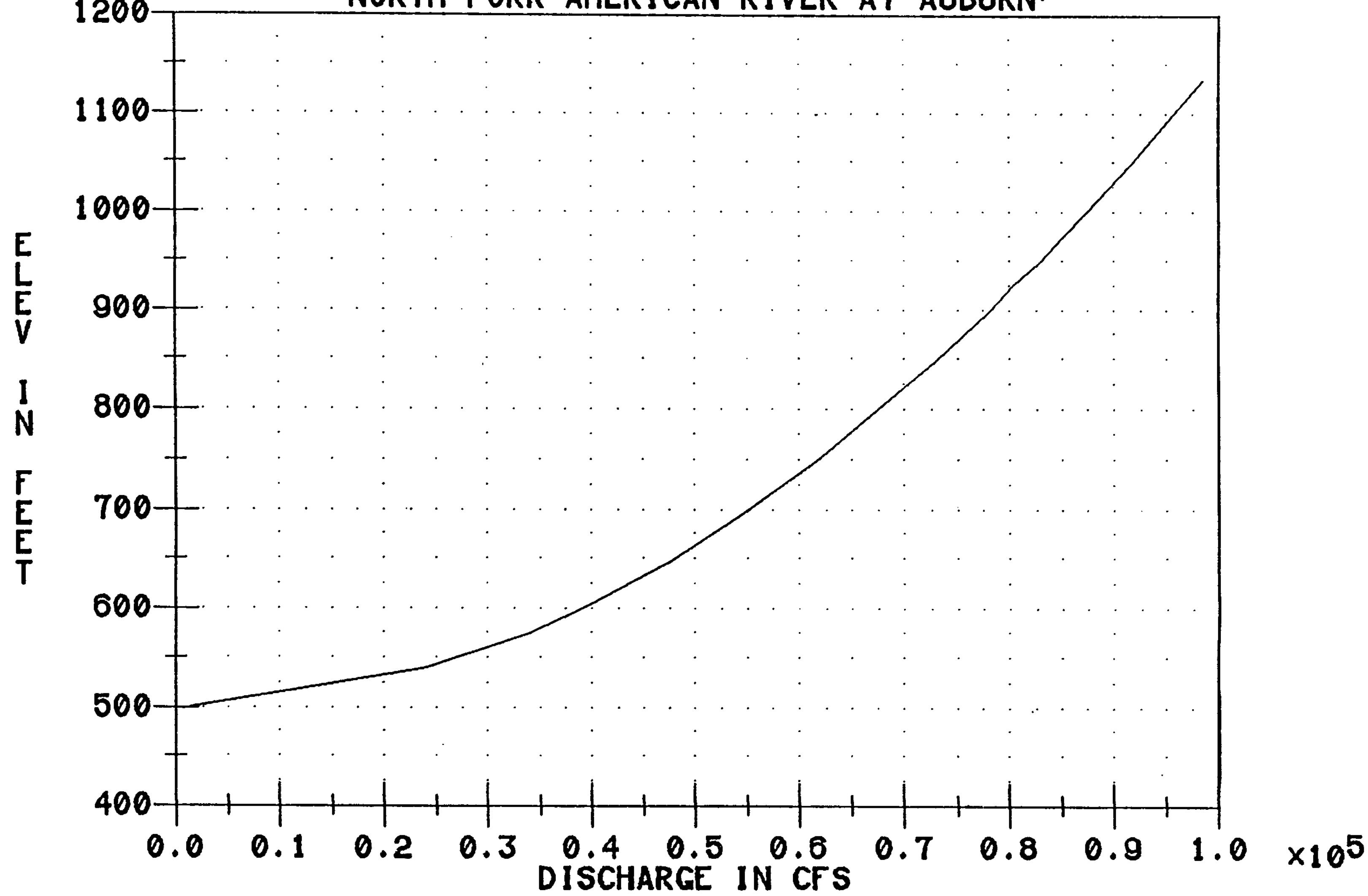

AMERICAN RIVER AT FAIR OAKS
FLOW IN CFS
450000
400000
350000
300000
250000
200000
150000
100000
50000
0
01
06
11
16
21
26
01
DAYS
UNREGULATED 200-YEAR FLOOD



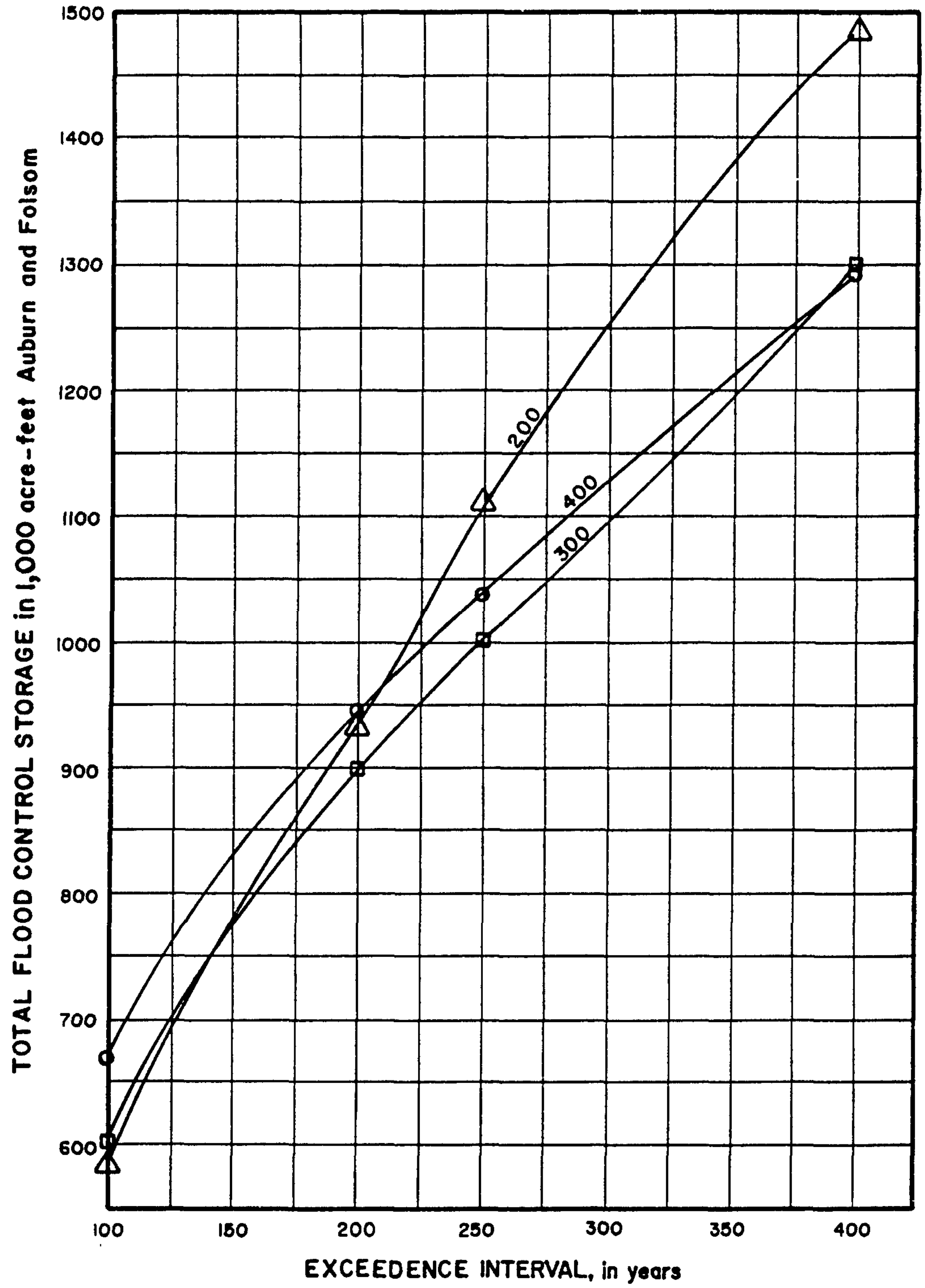
AMERICAN RIVER
FOLSOM DAM
OUTLET-SPILLWAY RATINGS
ELEVATION IN FEET - MSL
RIVER OUTLET FLOW IN CFS X 10,000
SPILLWAY FLOW IN CFS X 100,000
SPILLWAY (All 8 Gates)
RIVER OUTLETS (All 8)
MAIN SPILLWAY (5 Gates)
Gross Pool
Bottom of Flood Pool (400,000 acft Space)
480
470
460
450
440
430
420
410
400
0
1
2
3
4
5
6
7


ELEVATION-CAPACITY NORTH FORK AMERICAN RIVER
ELEV IN FEET
1200
1100
1000
900
800
700
600
500
400
0.0
0.5
1.0
1.5
2.0
2.5 ×10^6
STORAGE IN ACFT
RIVER MILE 20.1
RIVER MILE 19.0

NORTH FORK AMERICAN RIVER AT AUBURN



RATING CURVE - EXISTING DIVERSION TUNNEL LINED TO DIAMETER OF 30 FEET (6DEC88)



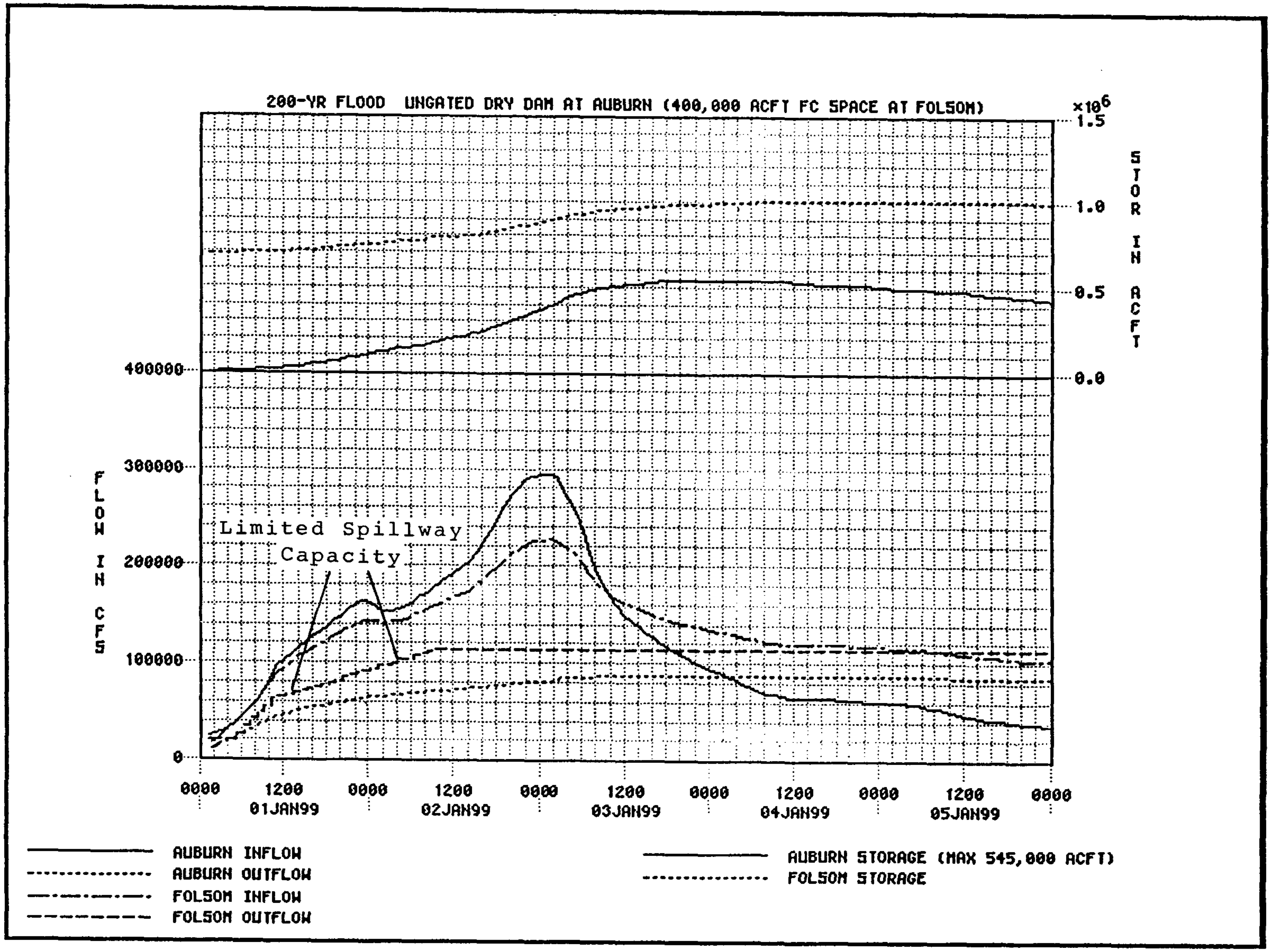
LEGEND:

400 Flood Control Storage Used at Folsom Lake (1,000 acre-feet)

STORAGE - EXCEEDENCE

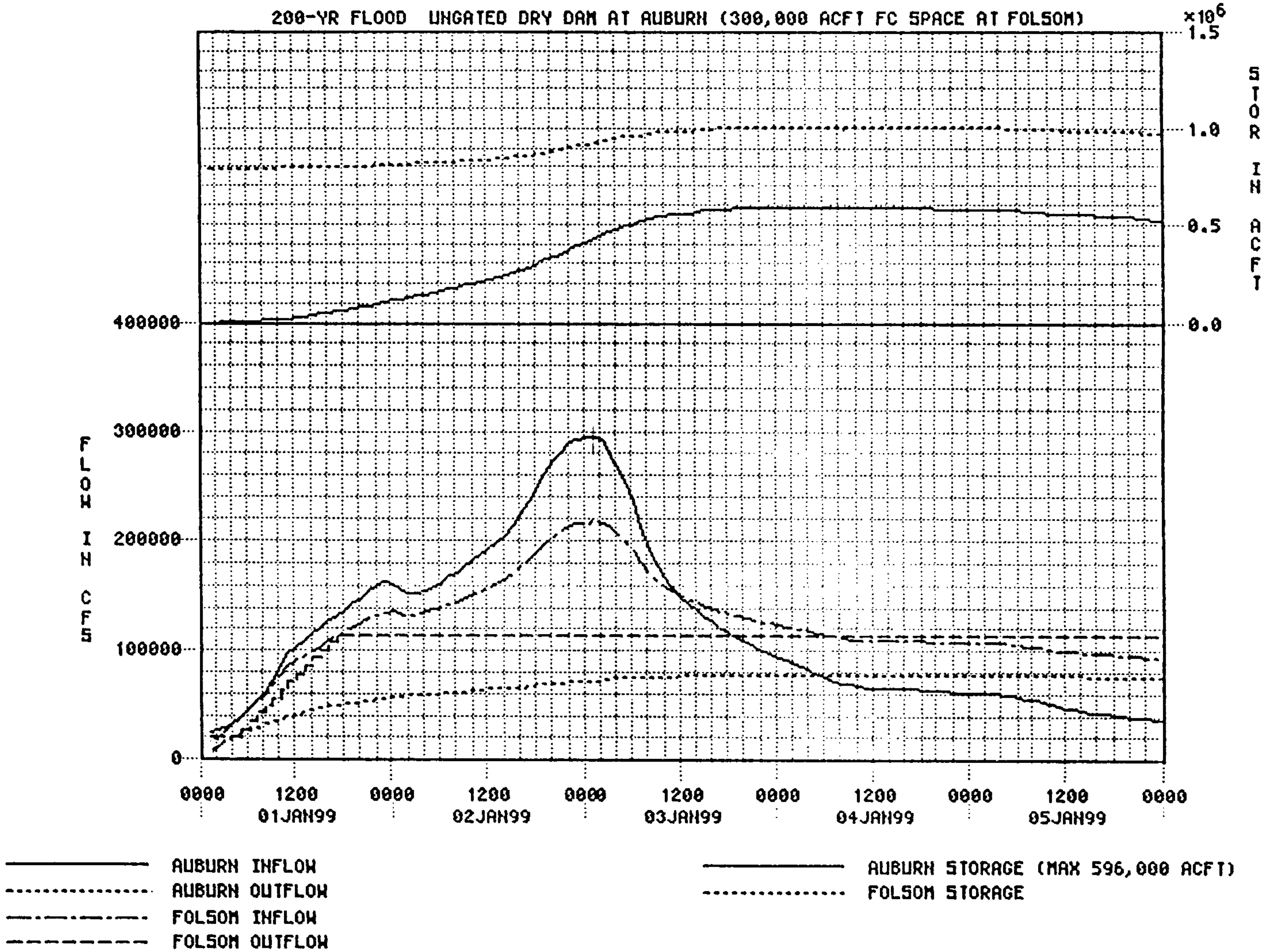
AUBURN DRY DAM OPTIMIZATION

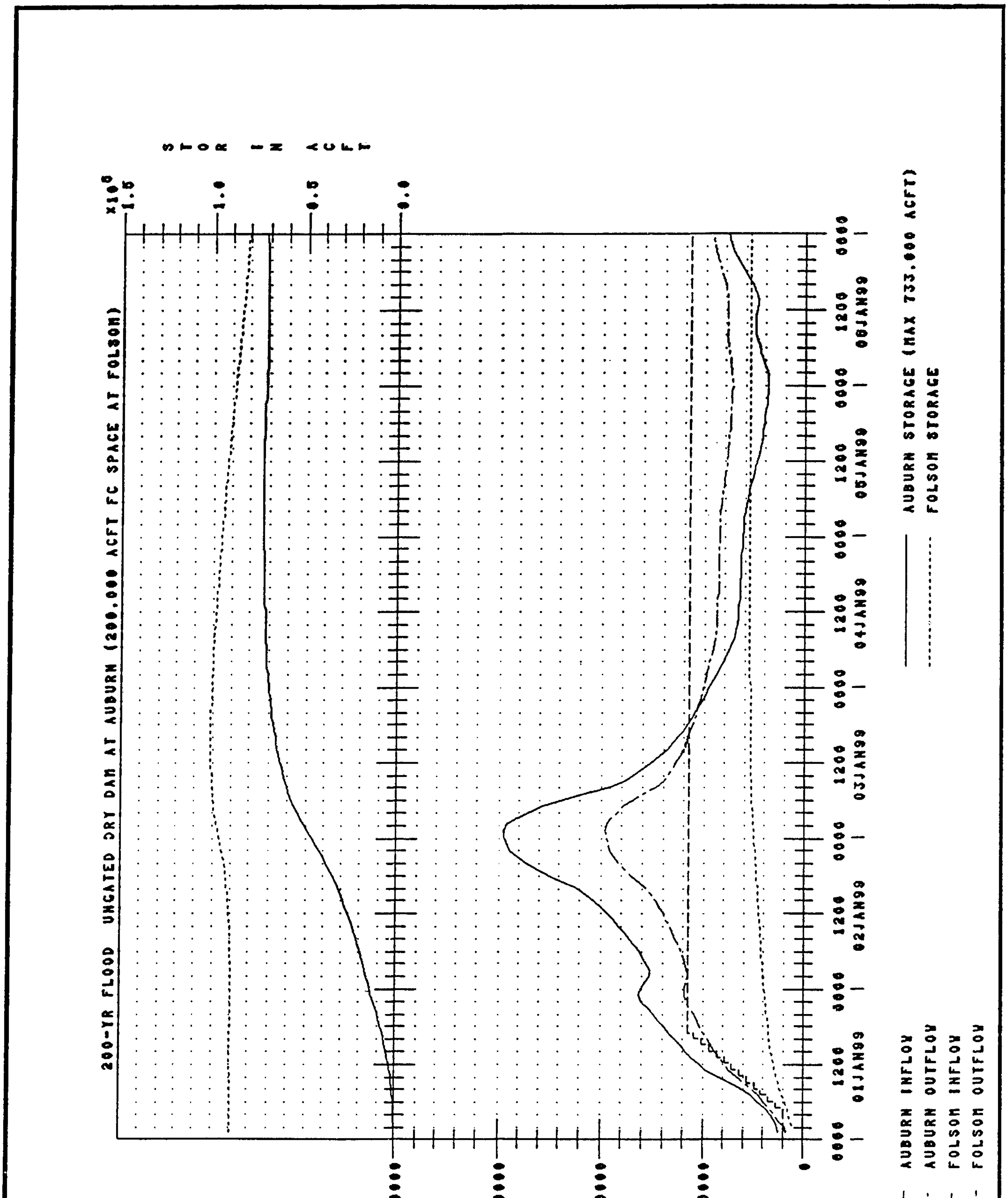
U.S. ARMY CORPS OF ENGINEERS
SACRAMENTO DISTRICT

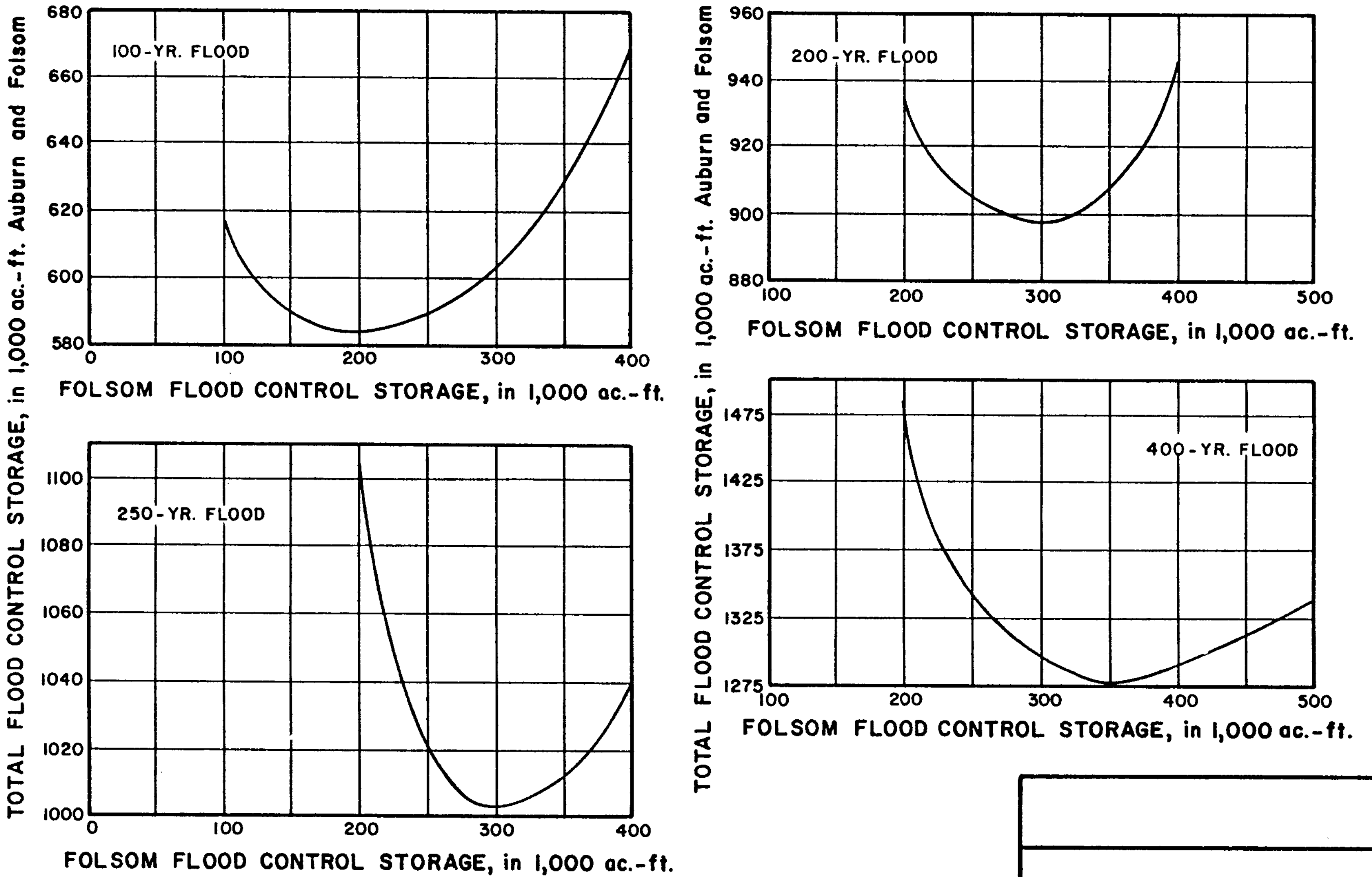


200-YR FLOOD UNGATED DRY DAM AT AUBURN (400,000 ACFT FC SPACE AT FOLSOM)
FLOW IN CFS
STOR IN ACFT
$\times 10^6$
1.5
1.0
0.5
0.0
400000
300000
200000
100000
0
Limited Spillway Capacity
0000
1200
01JAN99
0000
1200
02JAN99
0000
1200
03JAN99
0000
1200
04JAN99
0000
1200
05JAN99
0000
AUBURN INFLOW
AUBURN OUTFLOW
FOLSOM INFLOW
FOLSOM OUTFLOW
AUBURN STORAGE (MAX 545,000 ACFT)
FOLSOM STORAGE

200-YR FLOOD UNGATED DRY DAM AT AUBURN (300,000 ACFT FC SPACE AT FOLSOM)

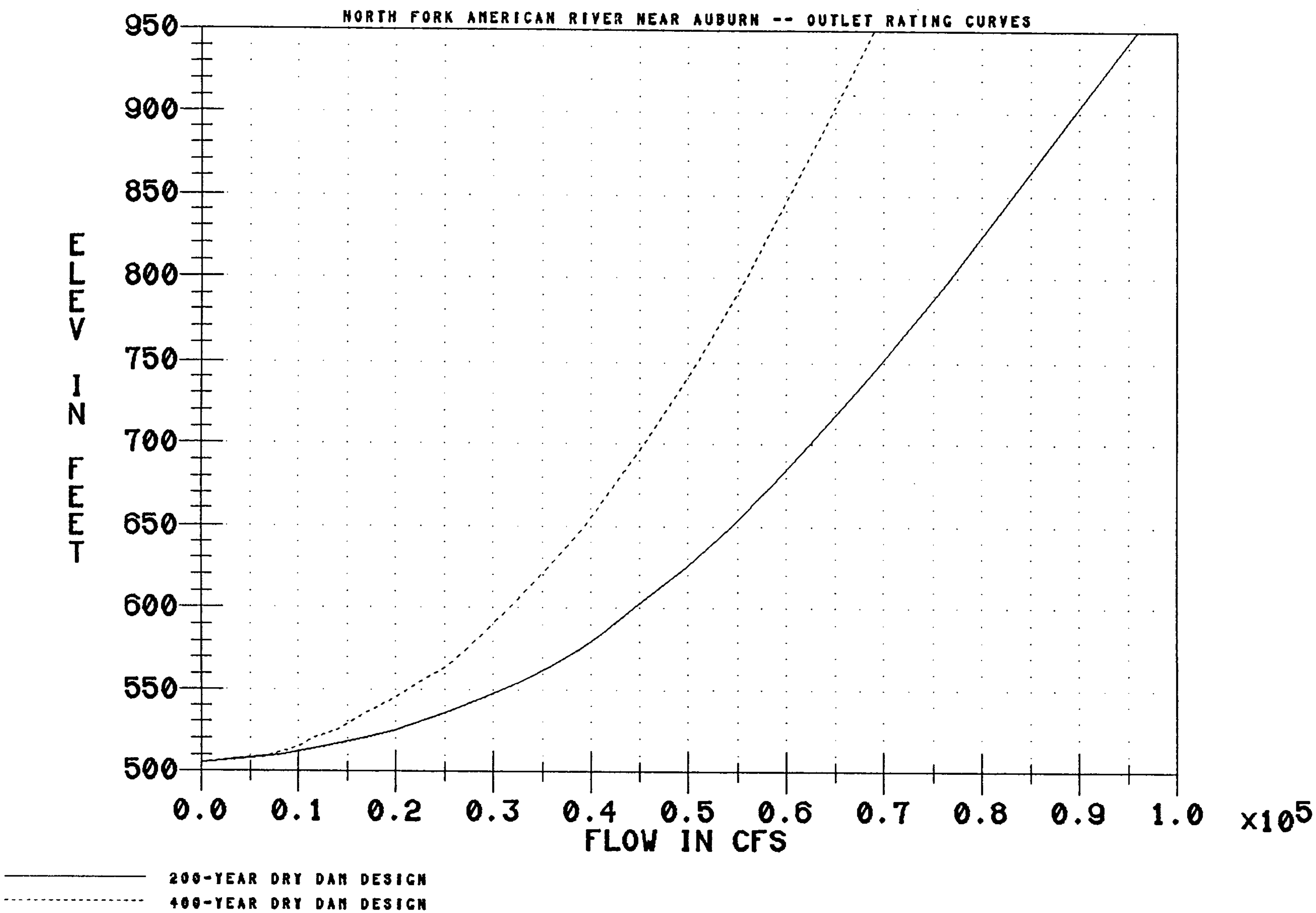


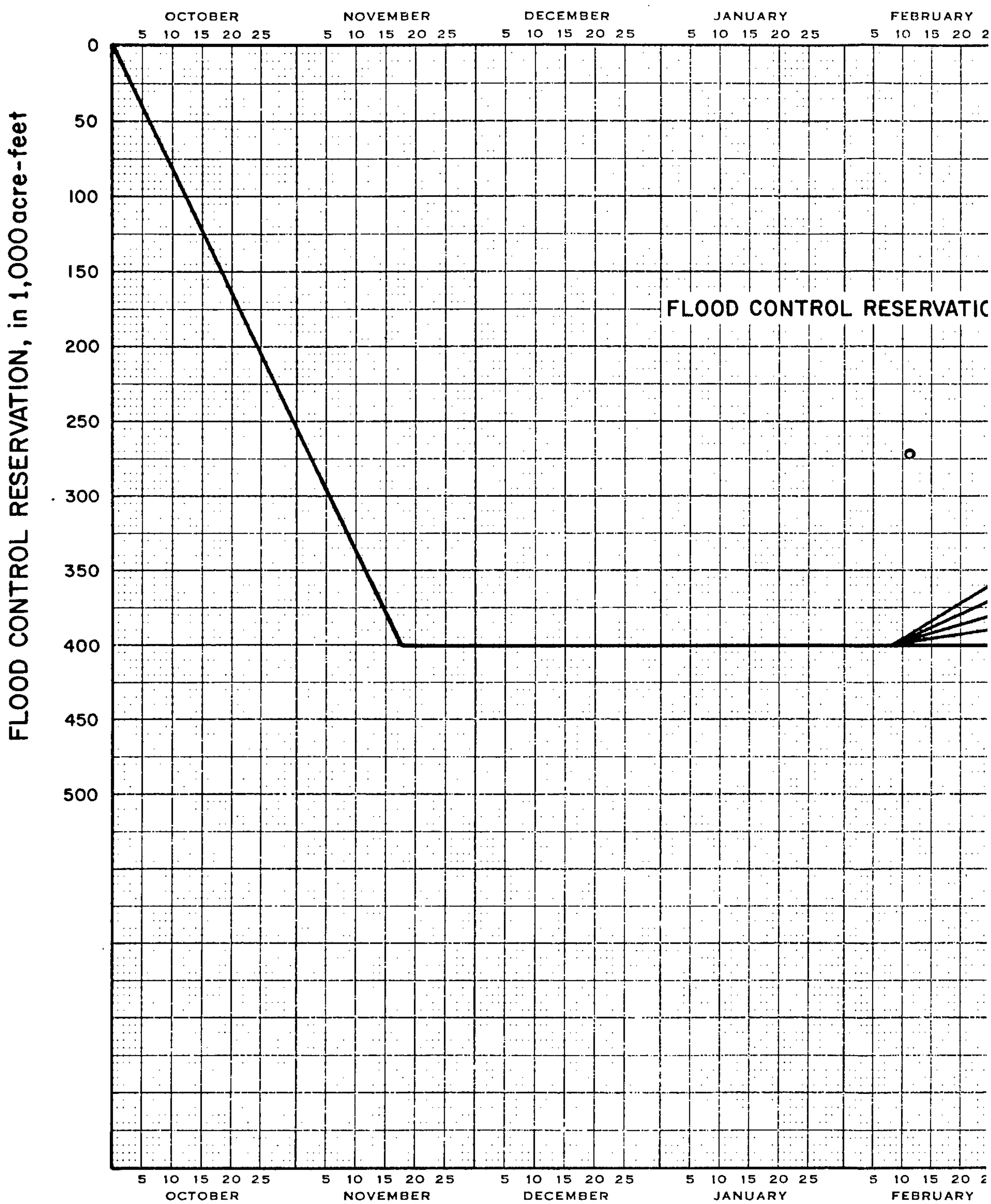

200-YR FLOOD UNGATED DRY DAM AT AUBURN (200,000 ACFT FC SPACE AT FOLSOM)
FLOW IN CFS
STOR IN ACFT
x10^6
1.5
1.0
0.5
0.0
400000
300000
200000
100000
0
0000
1200
01JAN99
0000
1200
02JAN99
0000
1200
03JAN99
0000
1200
04JAN99
0000
1200
05JAN99
0000
1200
06JAN99
0000
AUBURN INFLOW
AUBURN OUTFLOW
FOLSOM INFLOW
FOLSOM OUTFLOW
AUBURN STORAGE (MAX 733,000 ACFT)
FOLSOM STORAGE

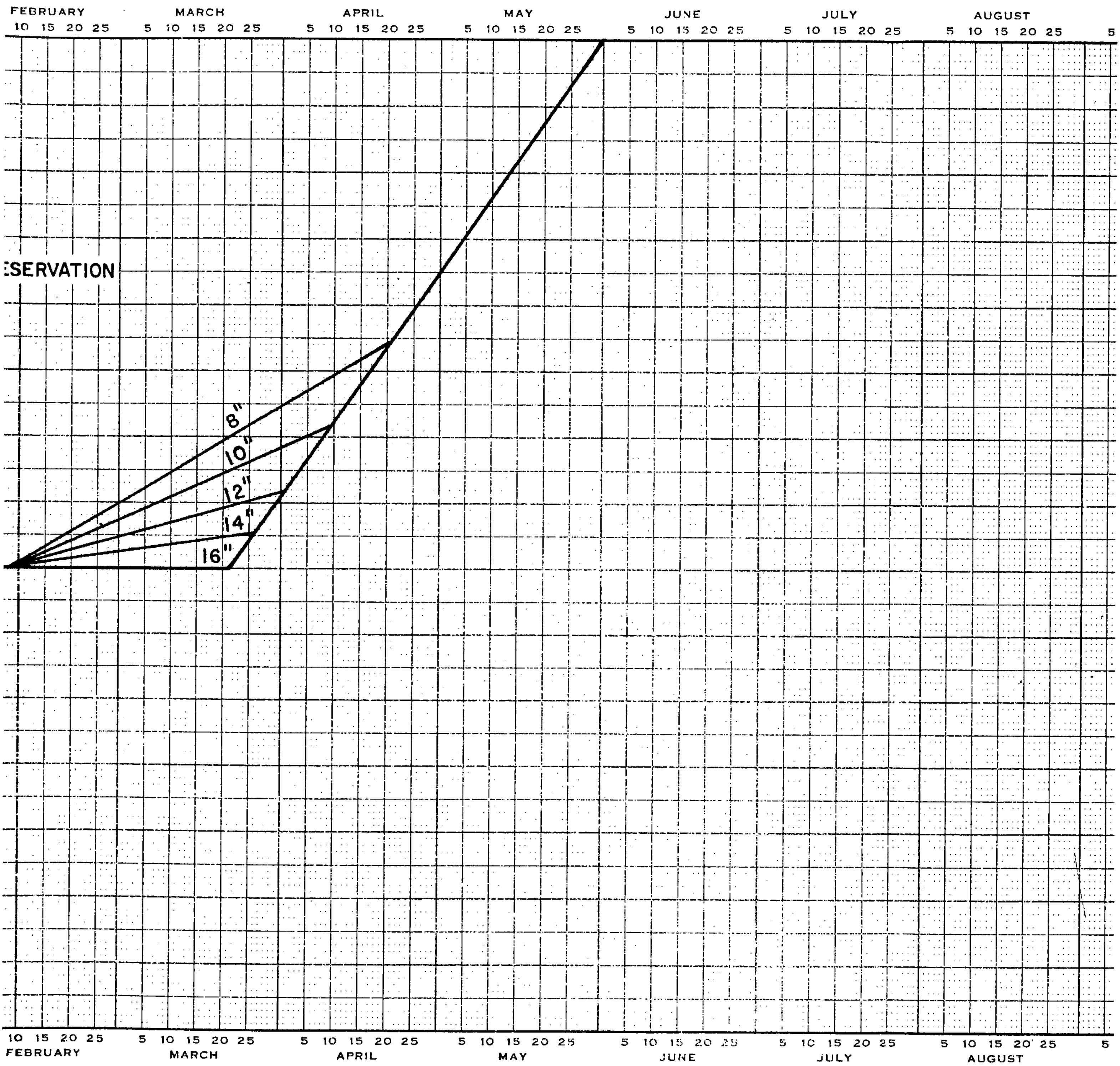


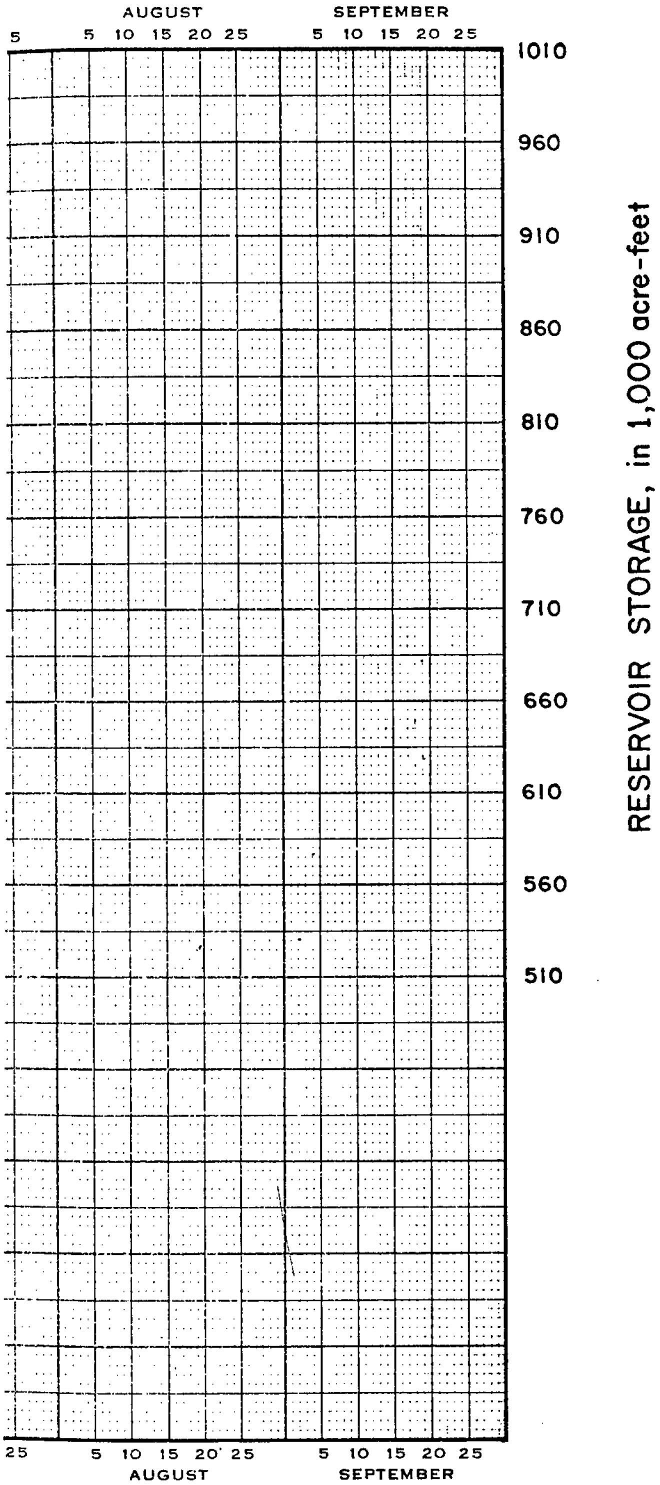
AUBURN-FOLSOM
FLOOD CONTROL STORAGE
AUBURN DRY DAM OPTIMIZATION

U.S. ARMY CORPS OF ENGINEERS
SACRAMENTO DISTRICT


NORTH FORK AMERICAN RIVER NEAR AUBURN -- OUTLET RATING CURVES
ELEV IN FEET
950
900
850
800
750
700
650
600
550
500
0.0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1.0
x10^5
FLOW IN CFS
200-YEAR DRY DAM DESIGN
400-YEAR DRY DAM DESIGN


FLOOD CONTROL RESERVATION, in 1,000 acre-feet
OCTOBER
NOVEMBER
DECEMBER
JANUARY
FEBRUARY
5 10 15 20 25
0
50
100
150
200
250
300
350
400
450
500
FLOOD CONTROL RESERVATIC


FEBRUARY MARCH APRIL MAY JUNE JULY AUGUST
10 15 20 25 5 10 15 20 25 5 10 15 20 25 5 10 15 20 25 5 10 15 20 25 5 10 15 20 25 5 10 15 20 25 5
:SERVATION
8"
10"
12"
14"
16"
10 15 20 25 5 10 15 20 25 5 10 15 20 25 5 10 15 20 25 5 10 15 20 25 5 10 15 20 25 5 10 15 20 25 5
FEBRUARY MARCH APRIL MAY JUNE JULY AUGUST



N

1. The objective of the Flood Control [
   protection to the Lower American River
   operational plan for the American River E

2. Flood Control Reservation is the flood cc
   When water is stored in this space, i
   requirements of this diagram.

USE OI

1. Rain flood parameters define the flood cc
   computed daily from the weighted accur
   adding the current day's precipitation ir
   preceding day.

2. Except when larger releases are required t
   Diagram, water stored within the Flooc
   released as rapidly as possible subject to

   a. Required Flood Control Release — M [1/]
      20,000 cfs when inflows are increasin

   b. Releases will not be increased more
      during any 2 hour period.

1/ Maximum inflow is the greatest inflow sinc

NOTES

1. The objective of the Flood Control Diagram is to provide an increased degree of protection to the Lower American River during the development of a revised flood control operational plan for the American River Basin.

2. Flood Control Reservation is the flood control space required under present authorization. When water is stored in this space, reservoir releases must be in accordance with requirements of this diagram.

USE OF DIAGRAM

1. Rain flood parameters define the flood control space reservation on any given day and are computed daily from the weighted accumulation of seasonal basin mean precipitation by adding the current day's precipitation in inches to 97% of the parameter computed the preceding day.

2. Except when larger releases are required by the accompanying Emergency Spillway Release Diagram, water stored within the Flood Control Reservation, defined hereon, shall be released as rapidly as possible subject to the following schedule:

   a. Required Flood Control Release [1/] — Maximum inflow up to 115,000 cfs but not less than 20,000 cfs when inflows are increasing.

   b. Releases will not be increased more than 15,000 cfs or decreased more than 10,000 cfs during any 2 hour period.

Maximum inflow is the greatest inflow since storage entered into Flood Control Reservation.

FOLSOM DAM AND LAKE
American River, California

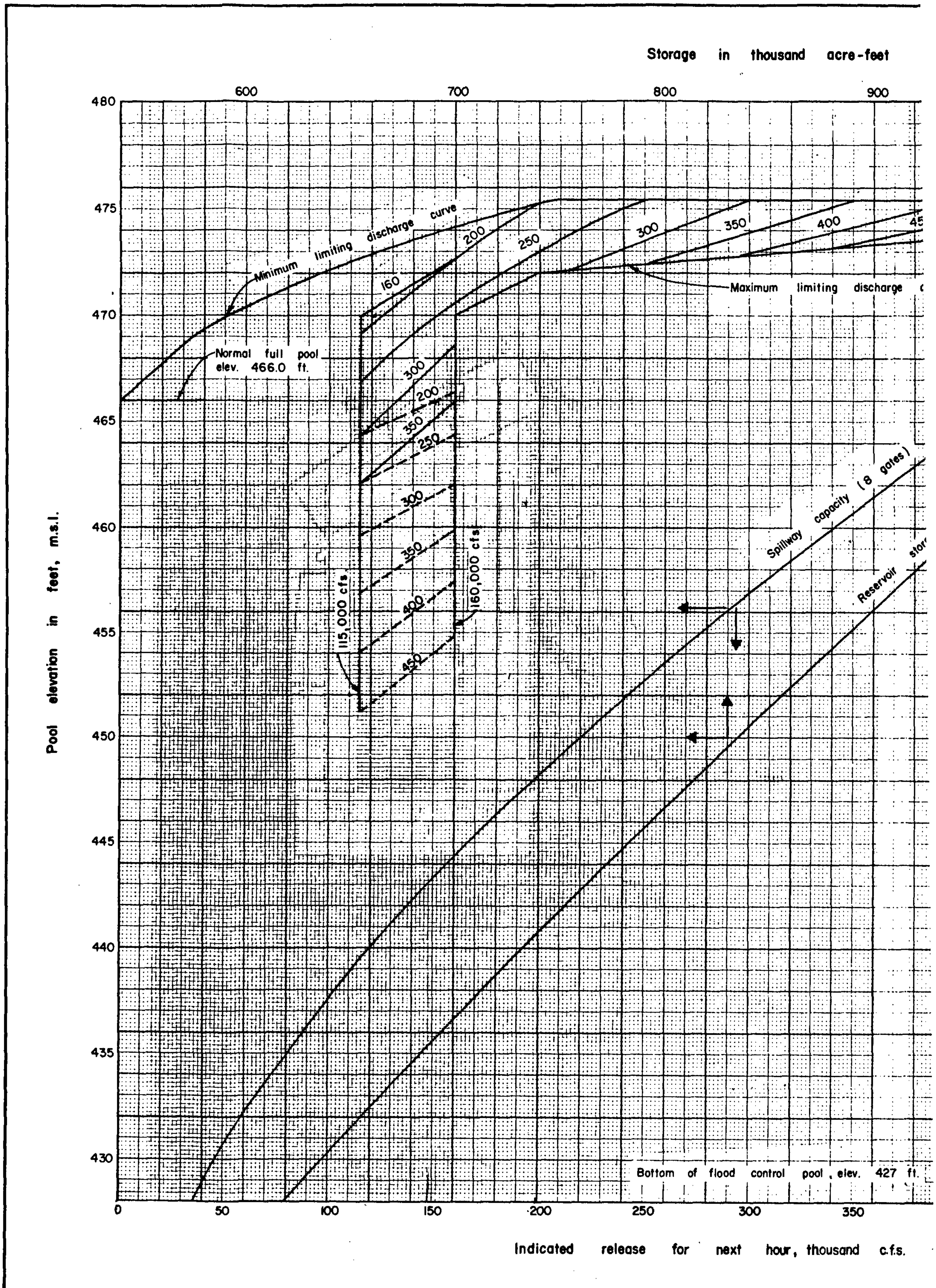
FLOOD CONTROL DIAGRAM

Prepared Pursuant to Flood Control Regulations for Folsom Dam and Lake in accordance with the Code of Federal Regulations Title 33 Part 208.11

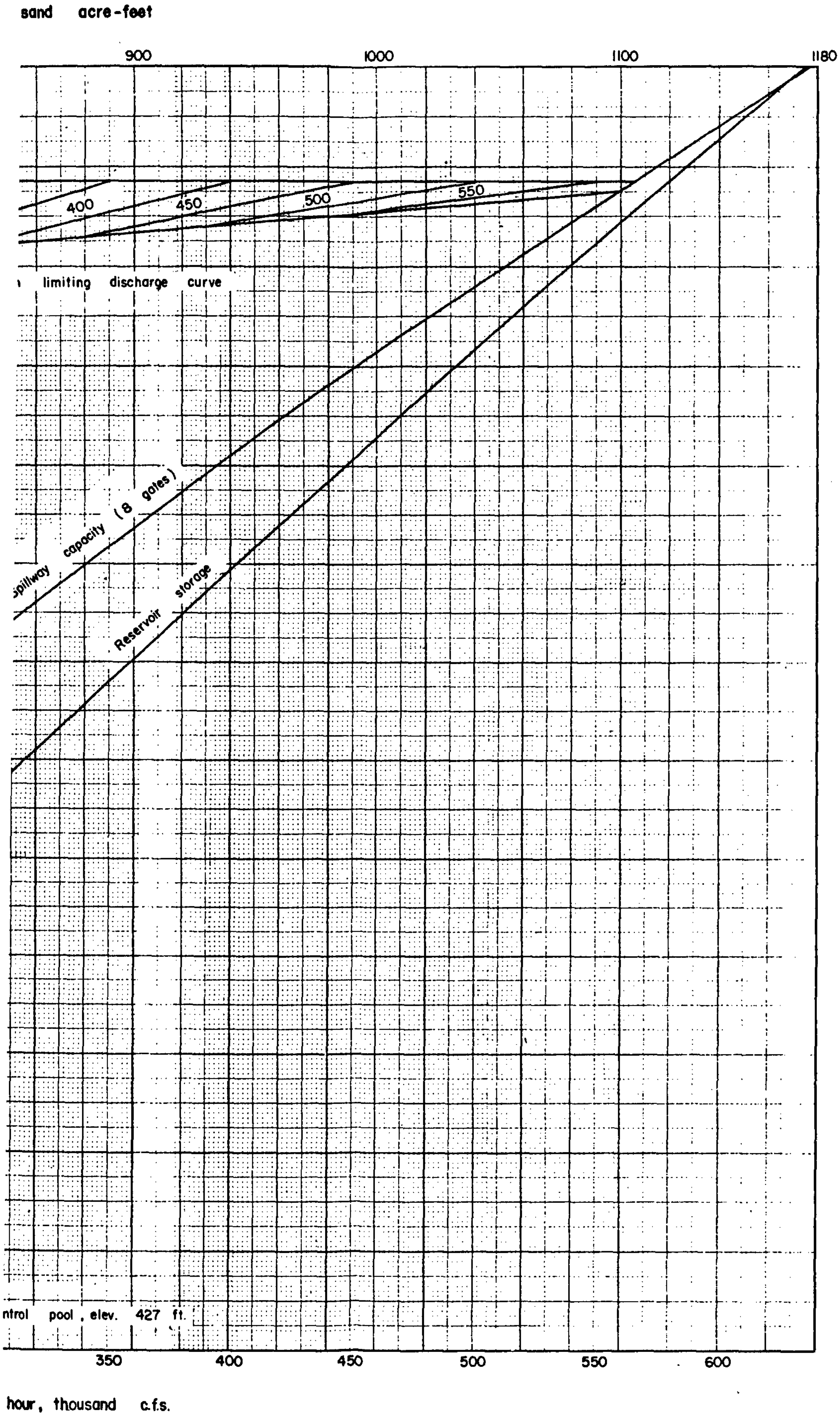
APPROVED Patrick J. Kelly
Brigadier General, USA, Division Engineer
South Pacific Division

APPROVED [signature]
Regional Director Mid Pacific Region
U.S.B.R.

Effective Date 7 November 1986 File No. AM-1-26-584



Storage in thousand acre-feet
600
700
800
900
480
475
470
465
460
455
450
445
440
435
430
Minimum limiting discharge curve
Maximum limiting discharge c
Normal full pool elev. 466.0 ft.
160
200
250
300
350
400
450
115,000 cfs
160,000 cfs
Spillway capacity (8 gates)
Reservoir stor
Bottom of flood control pool, elev. 427 ft.
Pool elevation in feet, m.s.l.
0
50
100
150
200
250
300
350
Indicated release for next hour, thousand c.f.s.



1. The following procedure should be
required by the Flood Control Dia

    a. Compute preceding hours inf

    b. When the stage has not exce
    c.f.'s. per hour. If the in
    dashed line parameter value

    c. When the stage is above nor
    hour enter diagram from exi

    d. Whenever the indicated rele
    schedule shown below. Use

2. Once releases based on this emerg
found herein, until the stage drc

POOL ELEVATION	CONDI
Less than elev. 448	
Elev. 448-470 rising pool	Downstre intact
Greater than elev. 470 rising pool	Downstre intact
Greater than elev. 448 falling pool	Downstre intact
Greater than elev. 448 falling pool	Downstre inoperat

TIME
0800
0900
1000
1100
1200
1300
1400
1500
1600

EMERGENCY SPILLWAY RELEASE DIAGRAM

OPERATING INSTRUCTIONS

e should be initiated whenever water is stored above elevation 448 feet m.s.l. and flood control releases are Control Diagram.

g hours inflow in thousand c.f.s. This is the parameter value used to enter diagram.

as not exceeded normal full pool (elev. 466 feet m.s.l.) determine if the inflow is increasing faster than 5,000 If the inflow is increasing faster than 5,000 c.f.s. per hour enter diagram from existing pool elevation. Find meter value and read indicated release.

s above normal full pool (elev. 466 feet m.s.l.) or the inflow is not increasing faster than 5,000 c.f.s. per am from existing pool elevation. Find solid line parameter value and read indicated release.

icated release is greater than 115,000 c.f.s., such release will be accomplished in accordance with the release elow. Use flood control diagram to determine release of 115,000 c.f.s. or less.

this emergency spillway release diagram are initiated, gate changes shall be made in accordance with the criteria e stage drops below elevation 448 feet m.s.l.

SCHEDULE FOR EMERGENCY SPILLWAY RELEASES

CONDITION	INDICATED RELEASE	ACTION
	0 to 115,000 c.f.s.	Follow F.C. Diagram
Downstream levees intact	115,000 to 160,000 c.f.s.	Increase outflows to indicated release at a rate of 15,000 c.f.s. per 2 hrs. Notify local authorities that evacuation of areas adjacent to downstream levees should be initiated. Do not reduce outflow while pool is rising.
Downstream levees intact	Greater than 160,000 c.f.s.	Increase outflow to indicated release but not greater than 160,000 c.f.s. until 6 hrs. has elapsed since flows greater than 115,000 were initiated.
Downstream levees intact	The lesser of 125% of inflow or maximum release during flood.	Make indicated release but do not reduce outflows below 115,000 c.f.s. until the reservoir pool has dropped below elev. 448.
Downstream levees inoperative	The lesser of 125% of inflow or maximum release during flood.	Make indicated release but do not reduce outflows below 50,000 c.f.s. until the reservoir pool has dropped below elev. 448.

EXAMPLE OF DIAGRAM UTILIZATION

TIME	POOL ELEV	MEAN INFLOW LAST HOUR	INDICATED RELEASE	OUTFLOW NEXT HOUR
0800	453.0	320,000	F.C. Diagram	115,000 c.f.s.
0900	459.7	340,000	150,000	130,000
1000	461.4	350,000	160,000	130,000
1100	463.1	356,000	160,000	145,000
1200	464.4	351,000	142,000	145,000
1300	466.0	340,000	154,000	154,000
1400	467.2	325,000	158,000	158,000
1500	468.3	295,000	153,000	158,000
1600	469.1	260,000	144,000	158,000

FOLSOM DAM AND LAKE
American River, California

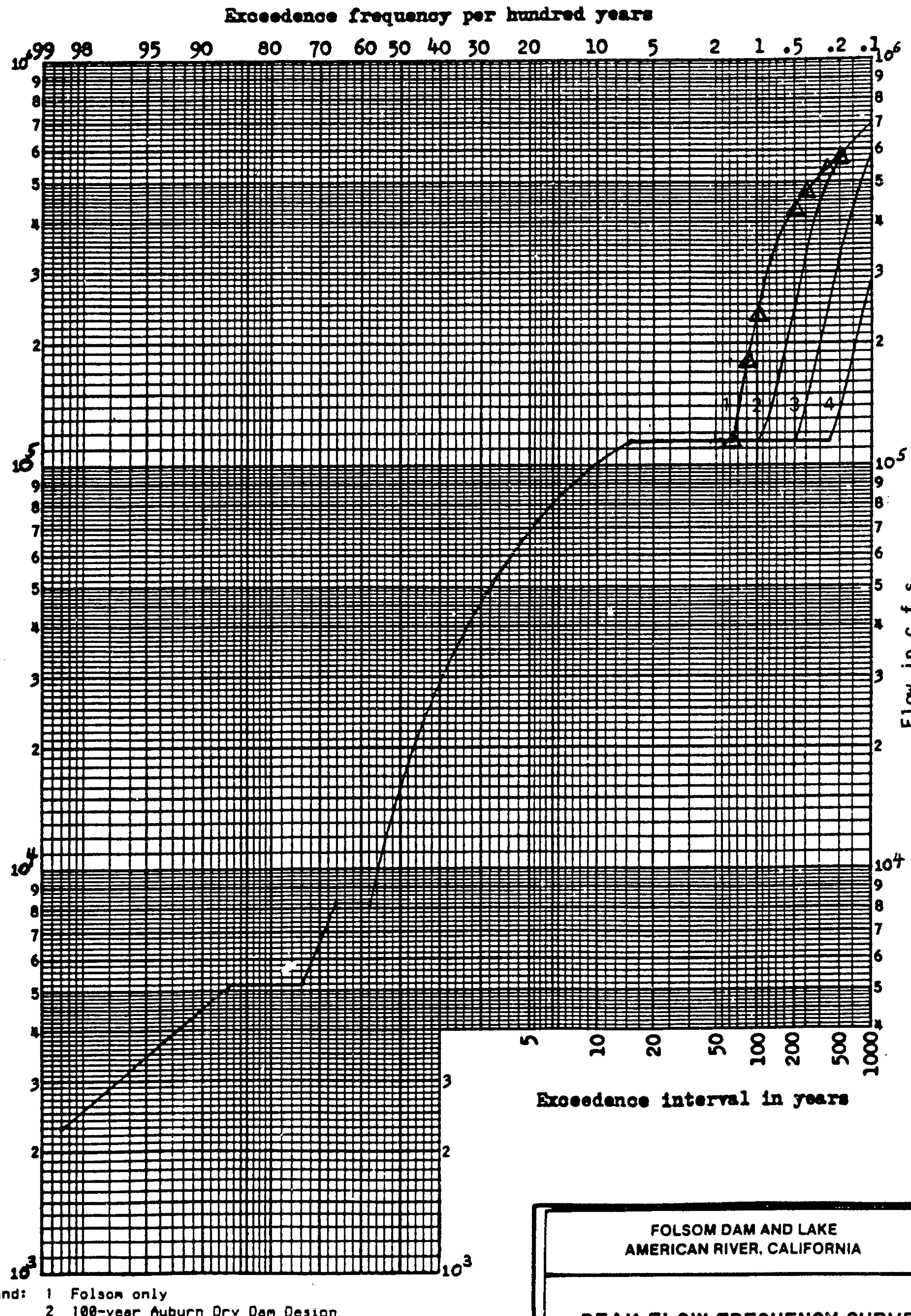
EMERGENCY SPILLWAY RELEASE DIAGRAM

Prepared Pursuant to Flood Control Regulations for Folsom Dam and Lake in accordance with the Code of Federal Regulations Title 33 Part 208.11

APPROVED ______________________
Brigadier General, USA, Division Engineer
South Pacific Division

____
Regional Director Mid Pacific Region
U.S.B.R.

Effective Date 7 November 1986 File No. AM-1-26-584



Legend: 1 Folsom only
2 100-year Auburn Dry Dam Design
3 200-year Auburn Dry Dam Design
4 400-year Auburn Dry Dam Design

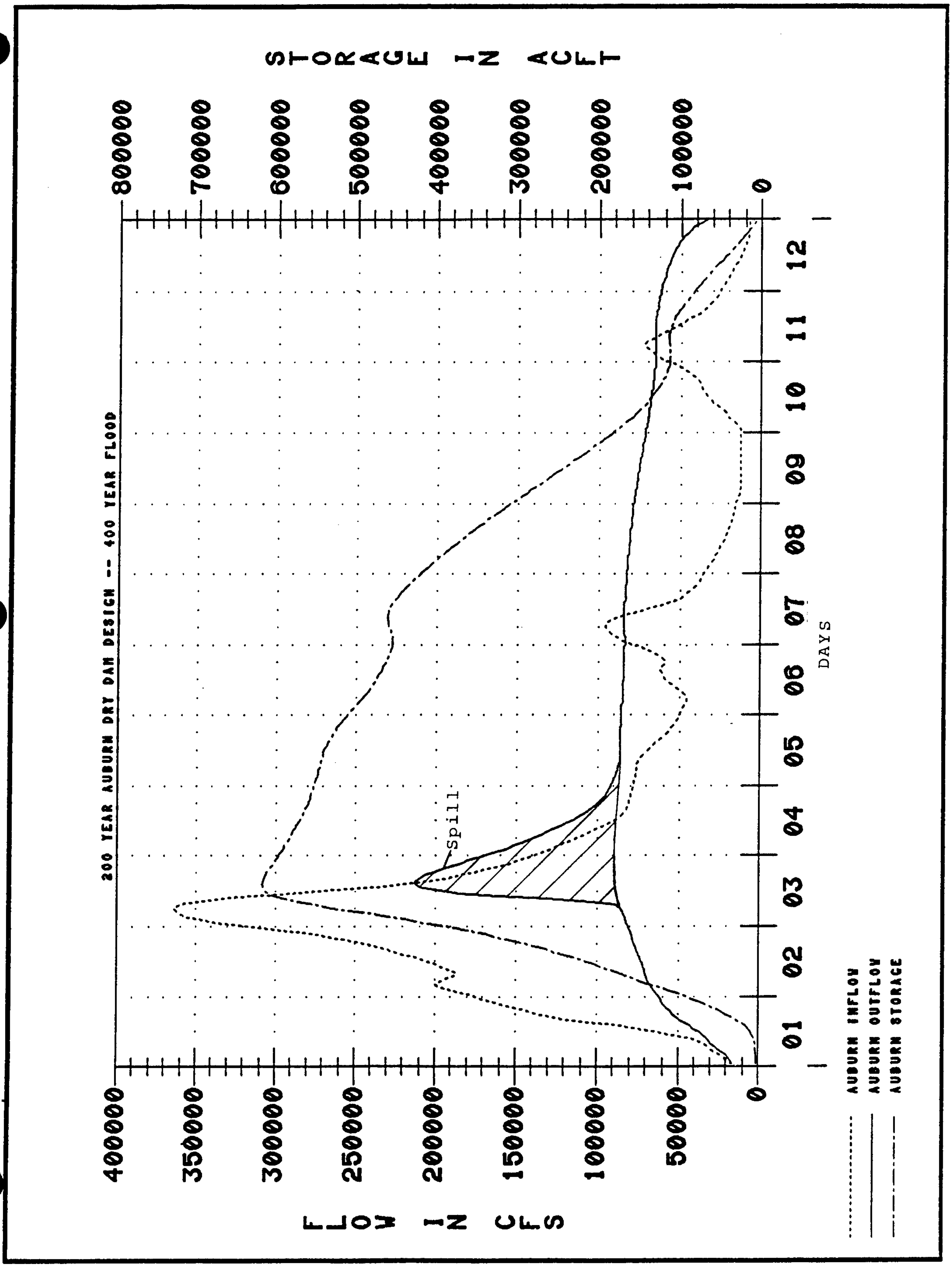
Note: The project curve to the 50-year event reflects 32 years of record (1955-1986). The remaining curves are the result of hypothetical routings assuming present authorized flood operation of Folsom Dam.

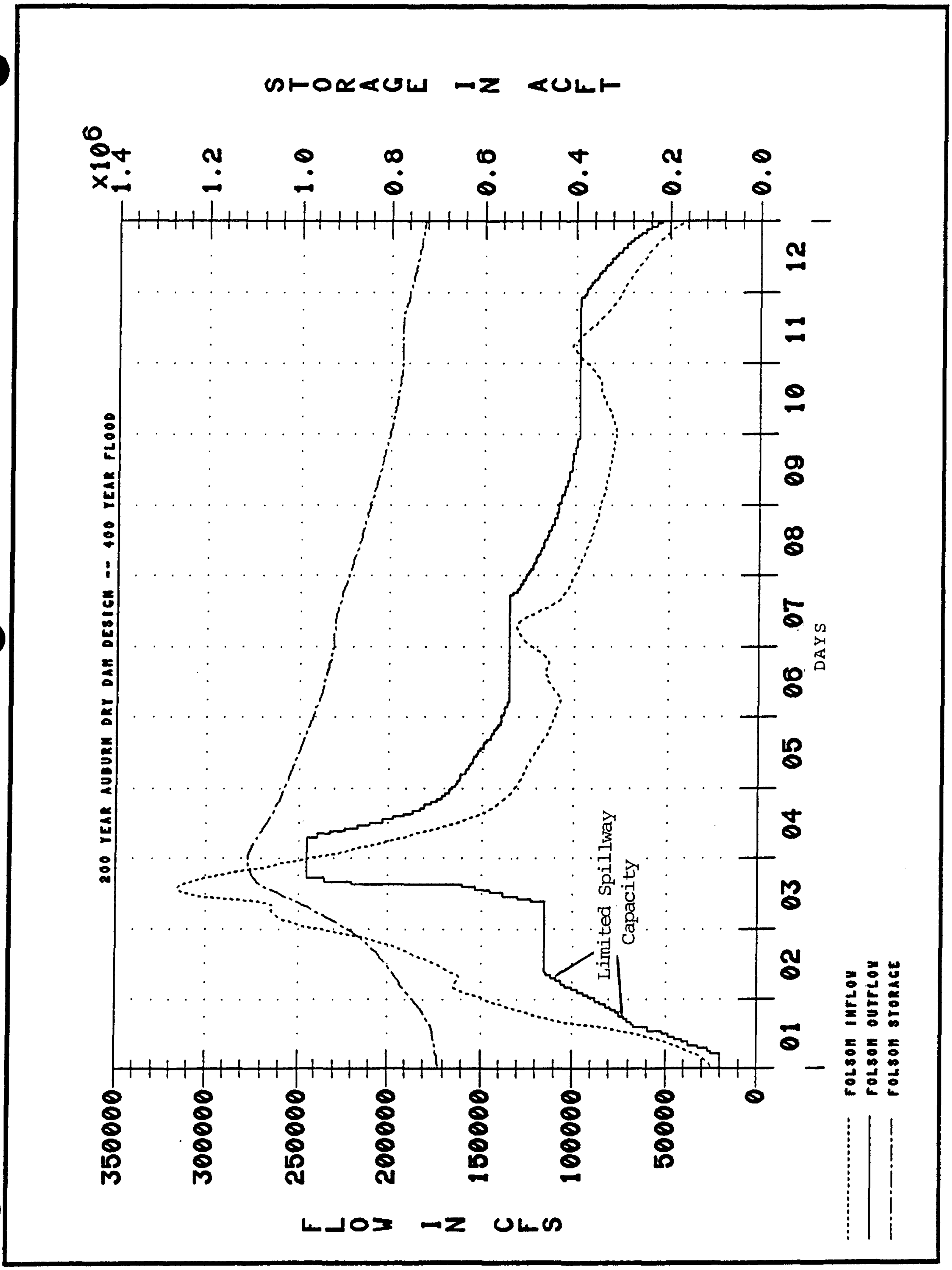
FOLSOM DAM AND LAKE
AMERICAN RIVER, CALIFORNIA

PEAK FLOW FREQUENCY CURVE

REGULATED CONDITIONS
AMERICAN RIVER AT FAIR OAKS

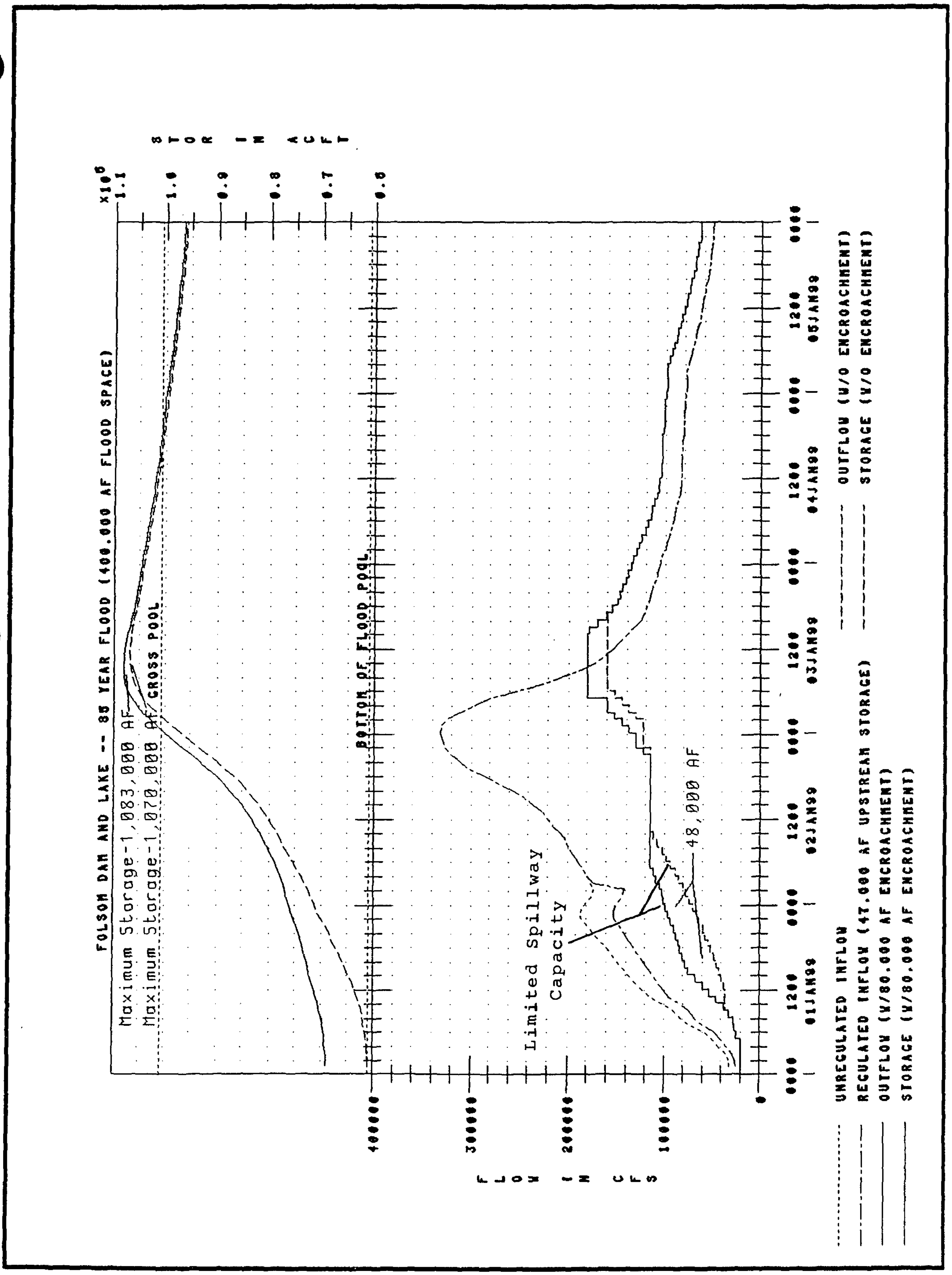
U.S. ARMY CORPS OF ENGINEERS
SACRAMENTO DISTRICT


200 YEAR AUBURN DRY DAM DESIGN -- 400 YEAR FLOOD
STORAGE IN ACFT
FLOW IN CFS
DAYS
Spill
AUBURN INFLOW
AUBURN OUTFLOW
AUBURN STORAGE
0
100000
200000
300000
400000
500000
600000
700000
800000
50000
150000
250000
350000
01
02
03
04
05
06
07
08
09
10
11
12

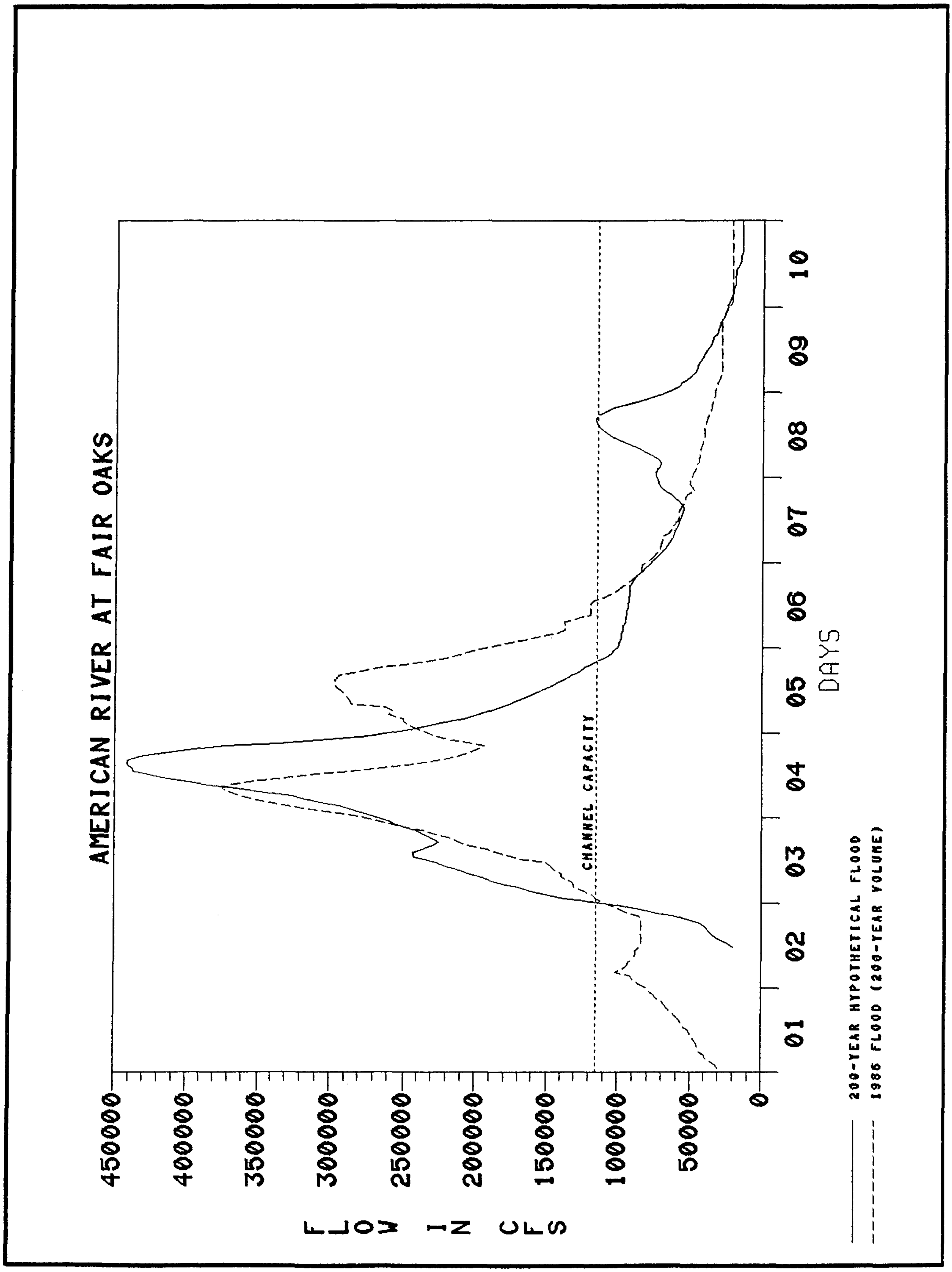


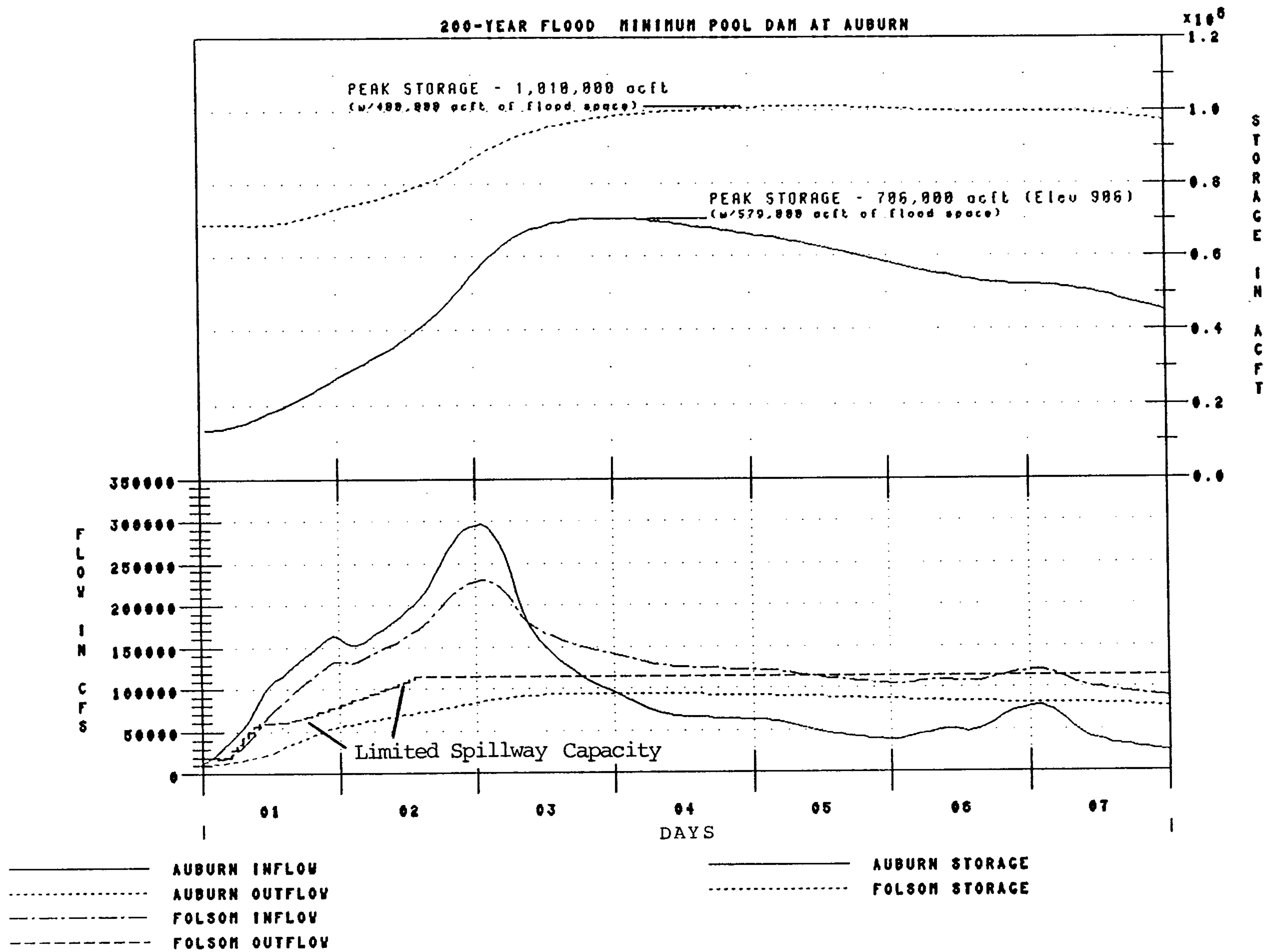
200 YEAR AUBURN DRY DAM DESIGN -- 400 YEAR FLOOD
FLOW IN CFS
STORAGE IN ACFT
X10^6
1.4
1.2
1.0
0.8
0.6
0.4
0.2
0.0
350000
300000
250000
200000
150000
100000
50000
0
01
02
03
04
05
06
07
08
09
10
11
12
DAYS
Limited Spillway Capacity
FOLSOM INFLOW
FOLSOM OUTFLOW
FOLSOM STORAGE

PLATE 17

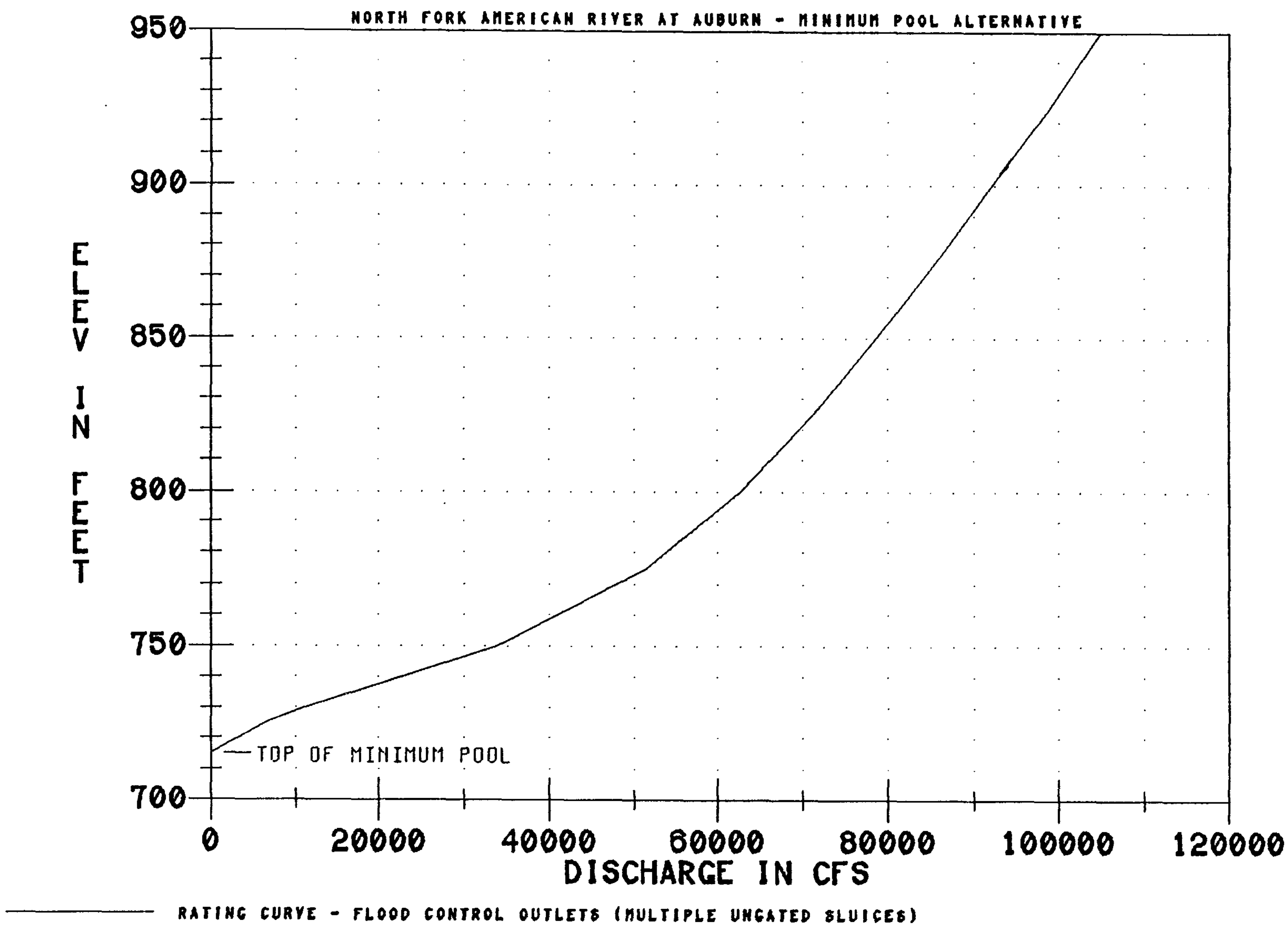


FOLSOM DAM AND LAKE -- 85 YEAR FLOOD (400,000 AF FLOOD SPACE)
Maximum Storage-1,083,000 AF
Maximum Storage-1,070,000 AF
GROSS POOL
BOTTOM OF FLOOD POOL
Limited Spillway Capacity
48,000 AF
FLOW IN CFS
STOR IN ACFT
x10^6
01JAN99
02JAN99
03JAN99
04JAN99
05JAN99
UNREGULATED INFLOW
REGULATED INFLOW (47,000 AF UPSTREAM STORAGE)
OUTFLOW (W/80,000 AF ENCROACHMENT)
STORAGE (W/80,000 AF ENCROACHMENT)
OUTFLOW (W/O ENCROACHMENT)
STORAGE (W/O ENCROACHMENT)

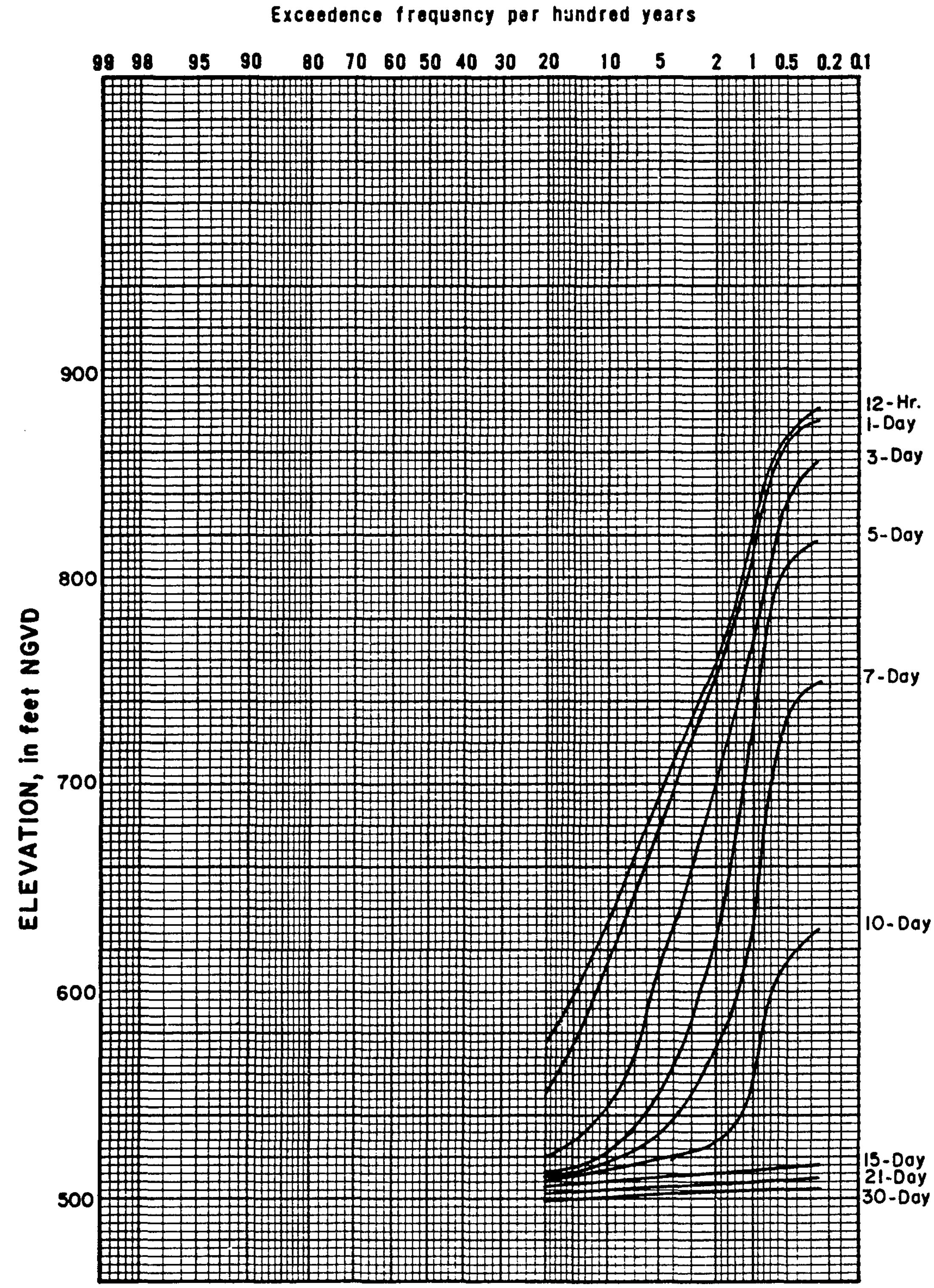

AMERICAN RIVER AT FAIR OAKS
FLOW IN CFS
450000
400000
350000
300000
250000
200000
150000
100000
50000
0
01
02
03
04
05
06
07
08
09
10
DAYS
CHANNEL CAPACITY
200-YEAR HYPOTHETICAL FLOOD
1986 FLOOD (200-YEAR VOLUME)



200-YEAR FLOOD MINIMUM POOL DAM AT AUBURN
PEAK STORAGE - 1,010,000 acft
(w/400,000 acft of flood space)
PEAK STORAGE - 706,000 acft (Elev 986)
(w/579,000 acft of flood space)
STORAGE IN ACFT
x10^6
1.2
1.0
0.8
0.6
0.4
0.2
0.0
FLOW IN CFS
350000
300000
250000
200000
150000
100000
50000
0
Limited Spillway Capacity
01
02
03
04
05
06
07
DAYS
AUBURN INFLOW
AUBURN OUTFLOW
FOLSOM INFLOW
FOLSOM OUTFLOW
AUBURN STORAGE
FOLSOM STORAGE



NORTH FORK AMERICAN RIVER AT AUBURN - MINIMUM POOL ALTERNATIVE
ELEV IN FEET
950
900
850
800
750
700
TOP OF MINIMUM POOL
0
20000
40000
60000
80000
100000
120000
DISCHARGE IN CFS
RATING CURVE - FLOOD CONTROL OUTLETS (MULTIPLE UNGATED SLUICES)

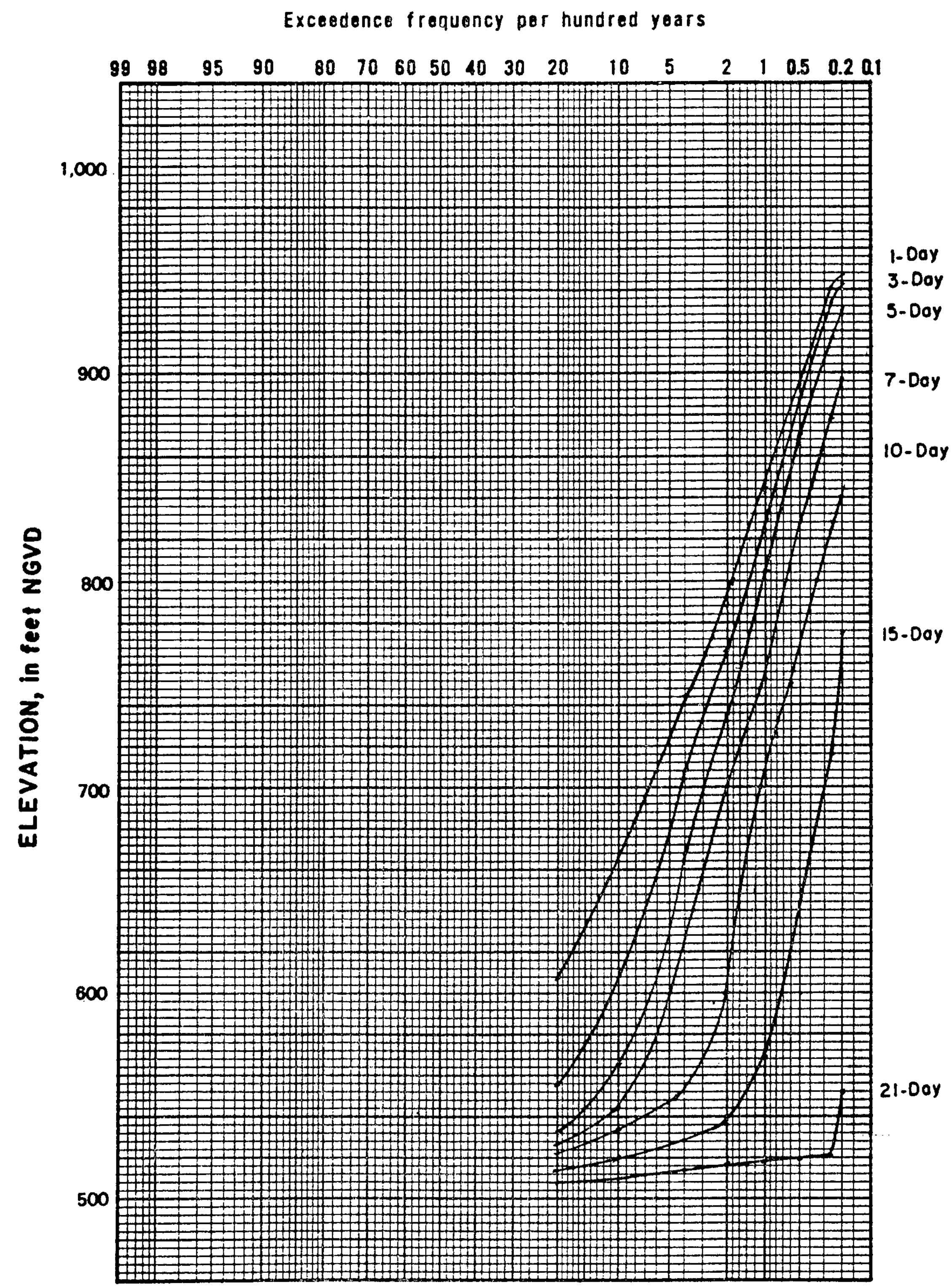


NOTES:

1. Dam located at River Mile 20.1 designed to control a 200-Yr. flood with 400,000 ac.-ft. of flood control space in Folsom Lake and a 115,000 cfs objective release.
2. Top of inactive pool - elevation 490.
3. Curves define the duration of time elevation is equalled or exceeded.

ELEVATION-FREQUENCY-DURATION
AUBURN DRY DAM ALTERNATIVE
(200-YEAR DESIGN)

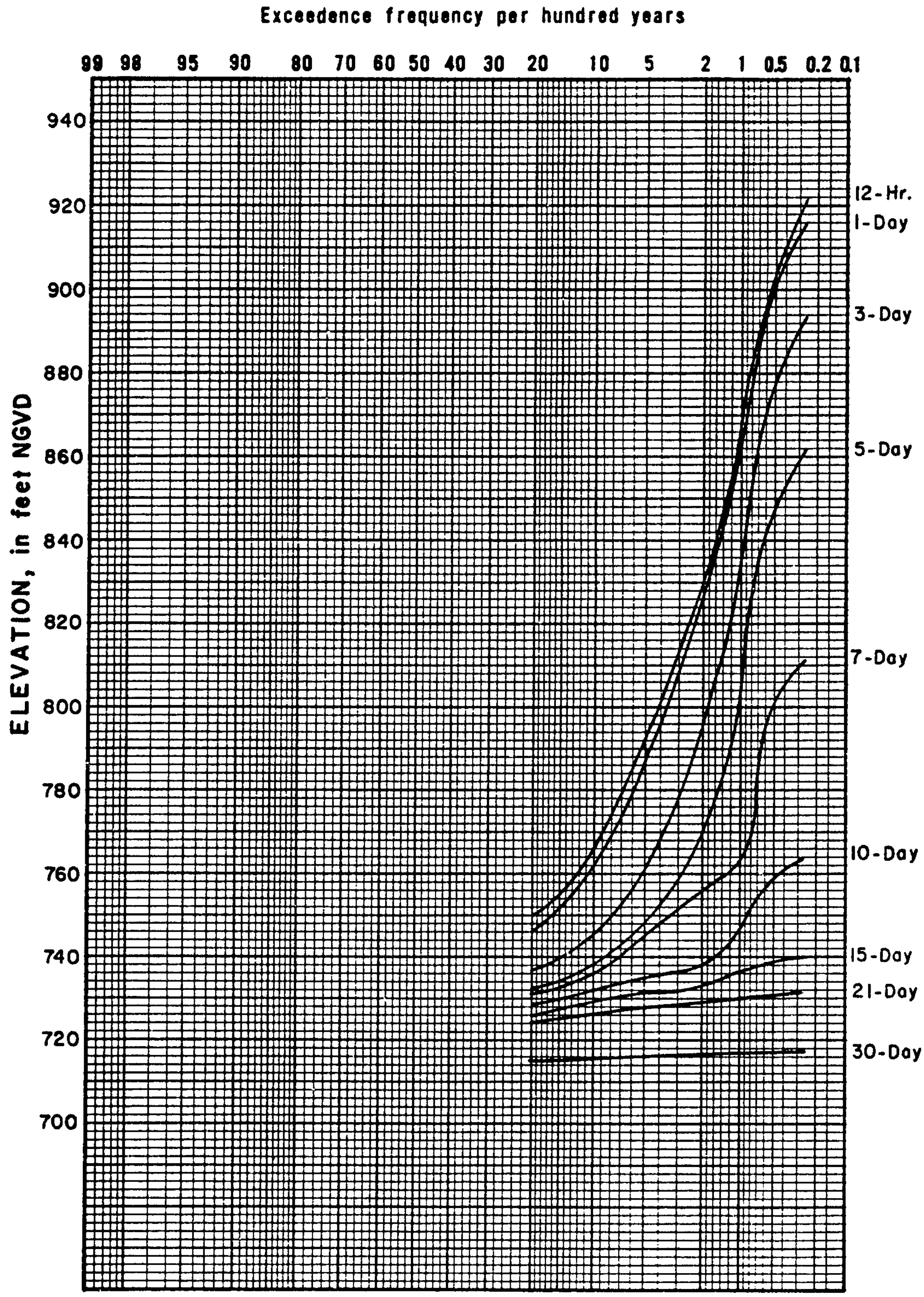
U.S. ARMY CORPS OF ENGINEERS
SACRAMENTO, DISTRICT



NOTES:
1. Dam located at River Mile 20.1 designed to control a 400-Yr. flood with 400,000 ac.-ft. of flood control space in Folsom Lake and a 115,000 cfs objective release.
2. Top of inactive pool - elevation 490.
3. Curves define the duration of time elevation is equalled or exceeded.

ELEVATION-FREQUENCY-DURATION
AUBURN DRY DAM ALTERNATIVE
(400-YEAR DESIGN)

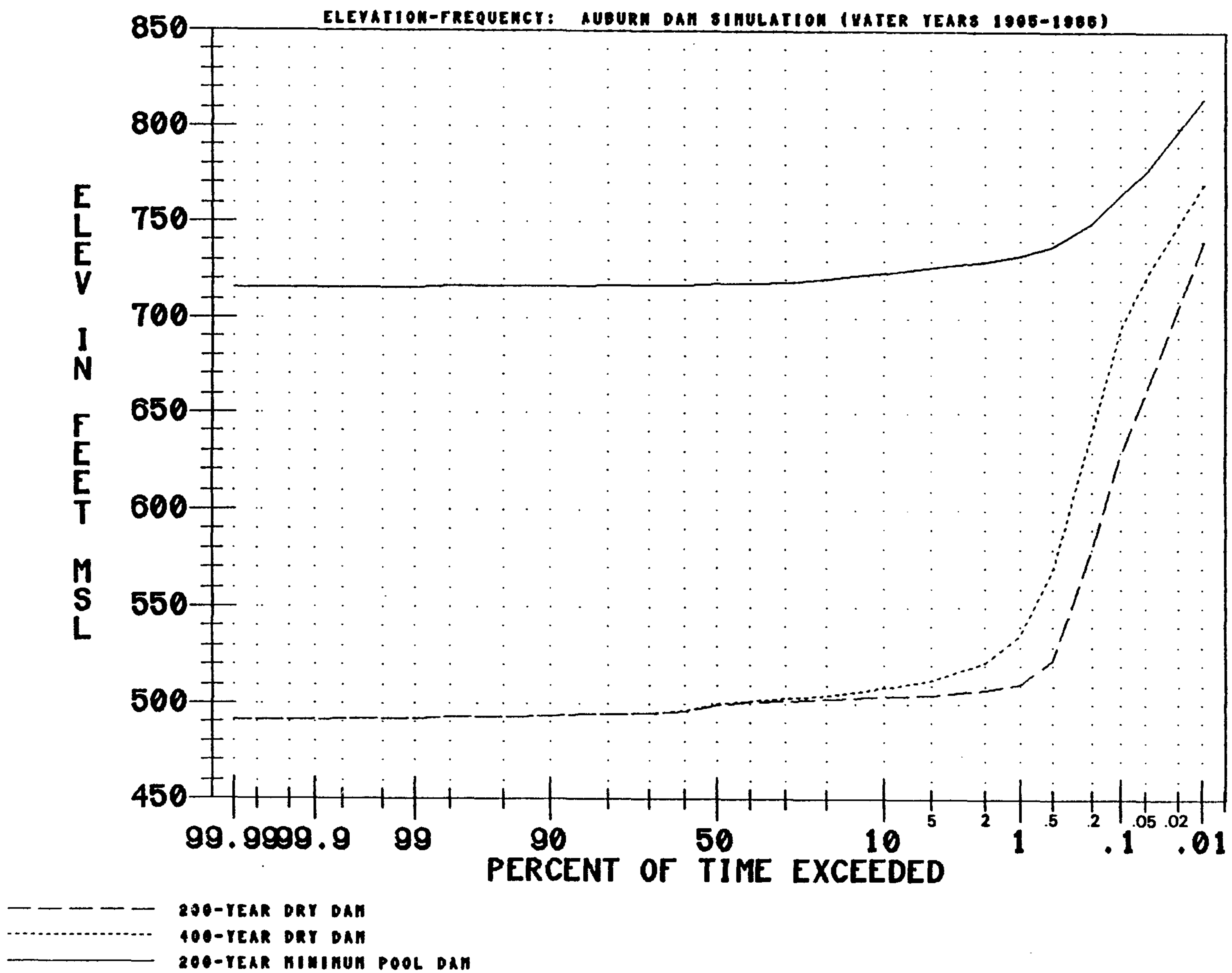
U.S. ARMY CORPS OF ENGINEERS
SACRAMENTO, DISTRICT

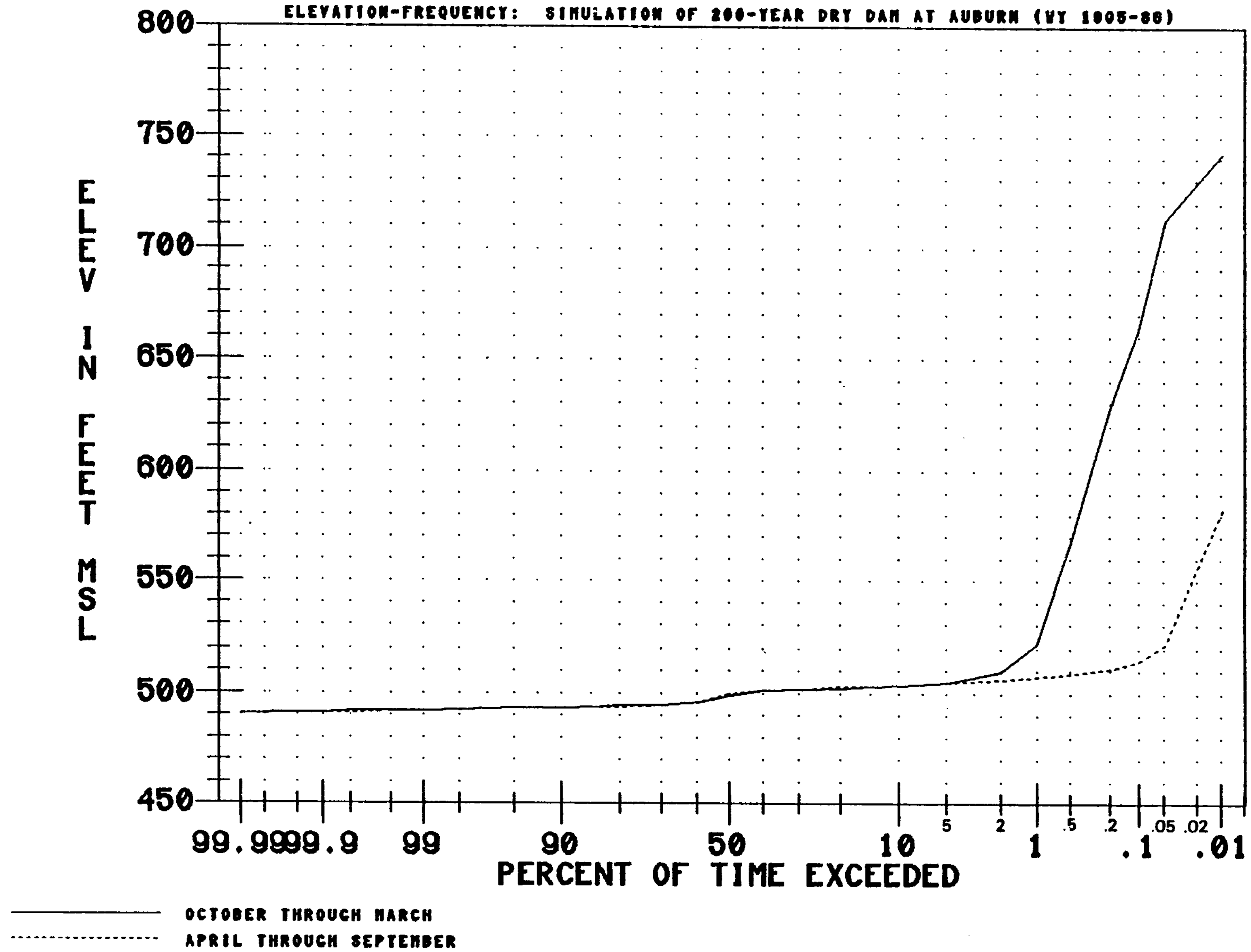


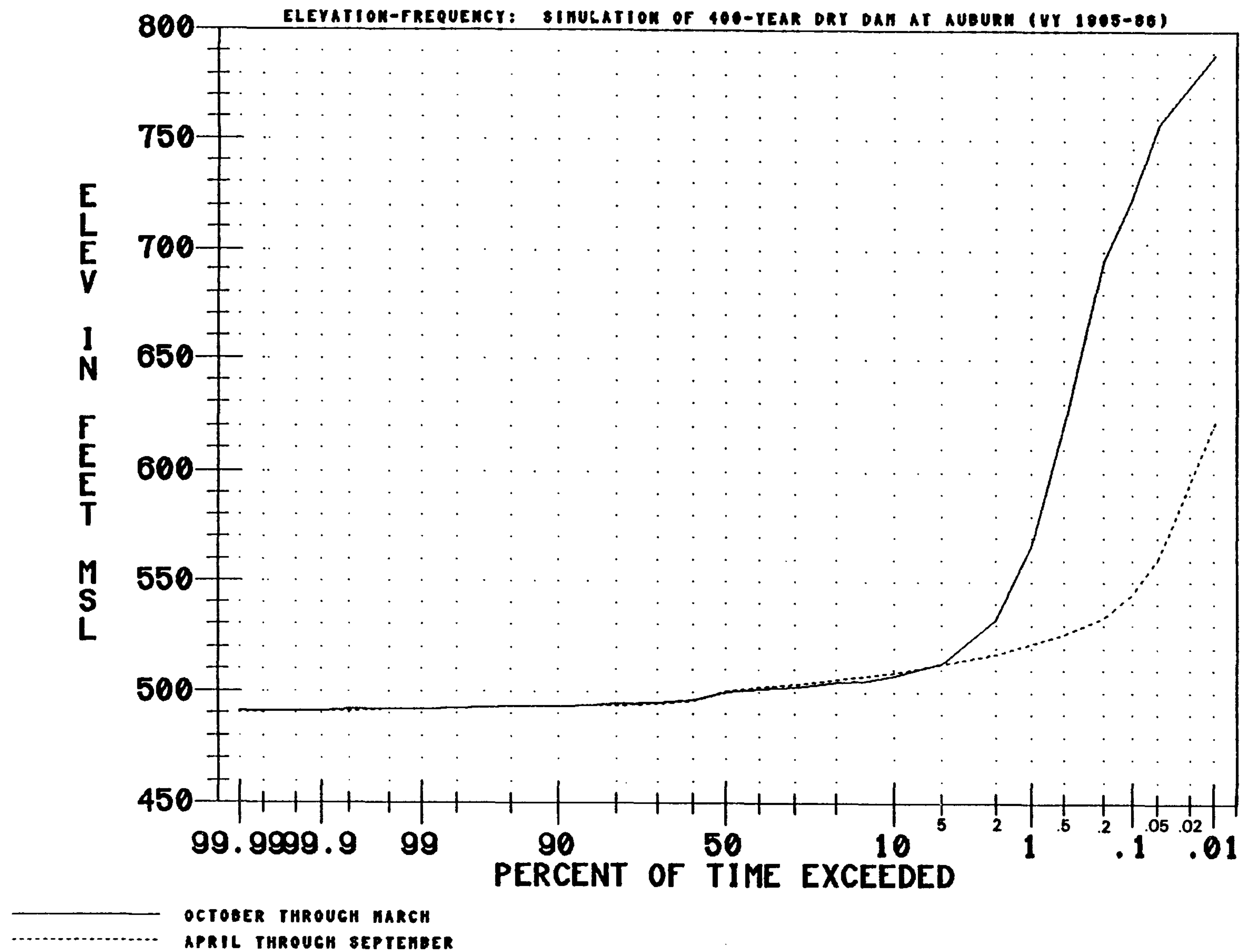
NOTES:
1. Dam located at River Mile 20.1 designed to control a 200-Yr. flood with 400,000 ac.-ft. of flood control space in Folsom Lake and a 115,000 cfs objective release.
2. Top of min. pool - elevation 715.
3. Curves define the duration of time elevation is equalled or exceeded.

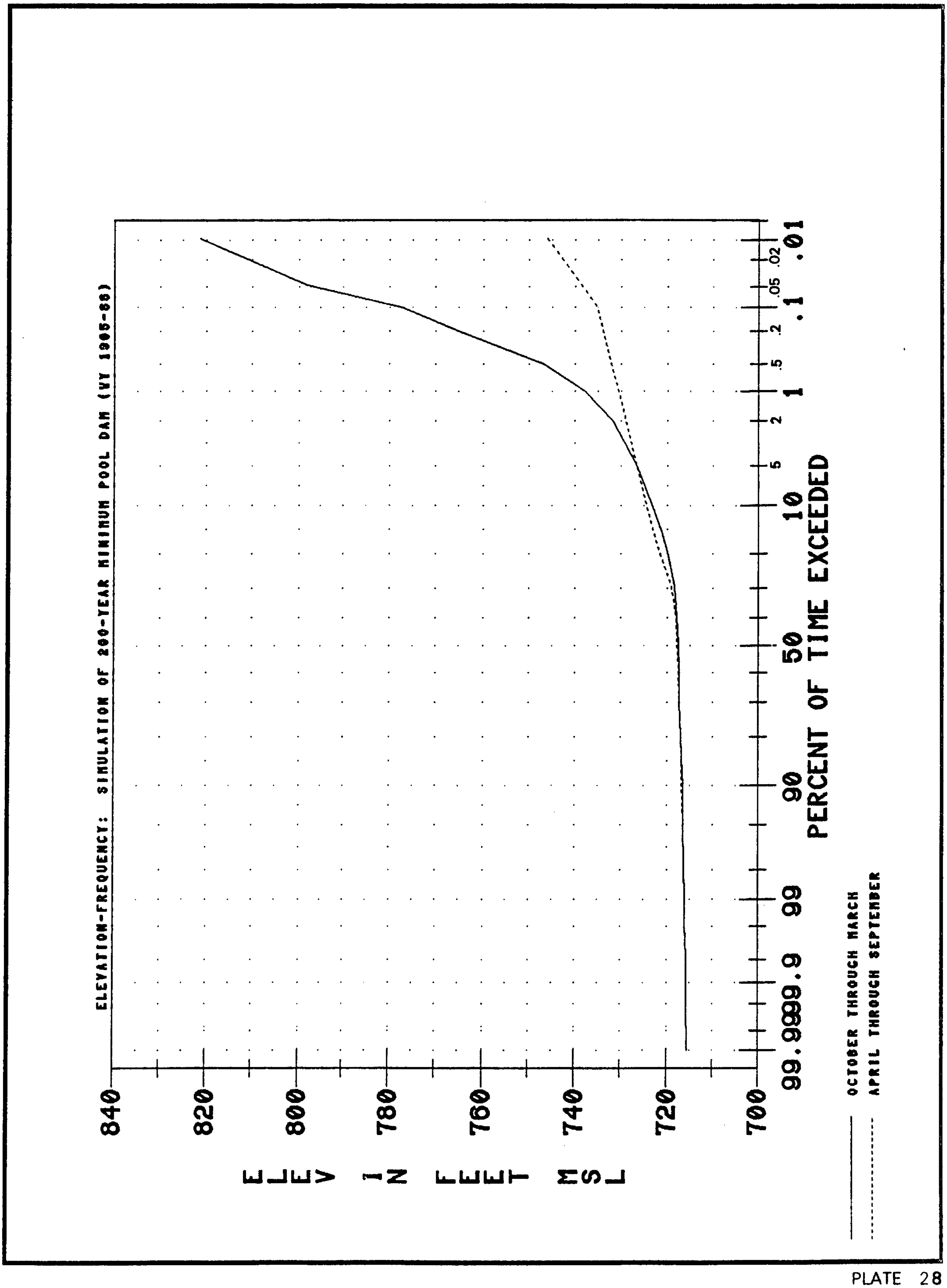
ELEVATION - FREQUENCY - DURATION
AUBURN MIN. POOL ALTERNATIVE
(200-YEAR DESIGN)

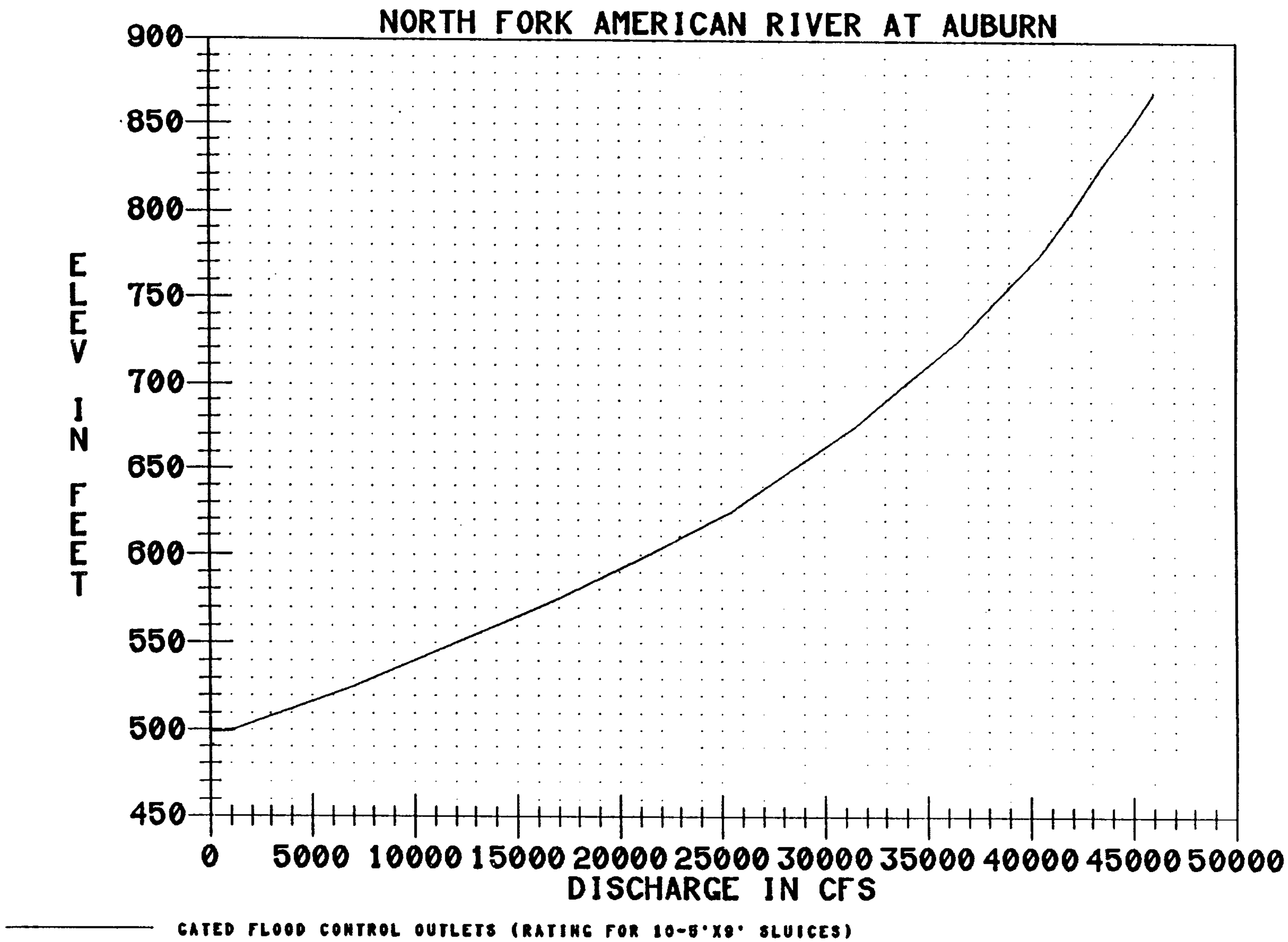
U.S. ARMY CORPS OF ENGINEERS
SACRAMENTO, DISTRICT

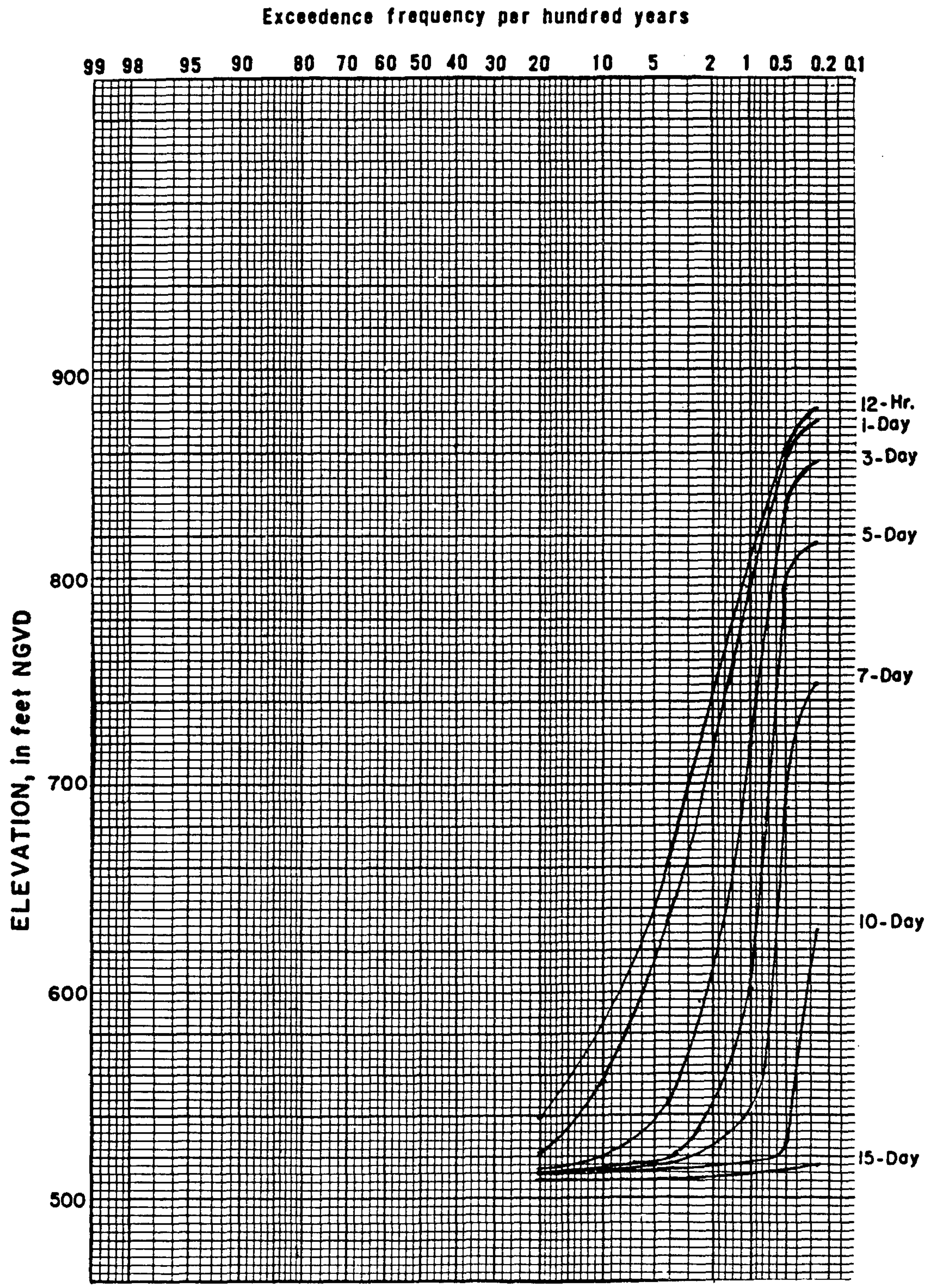

ELEVATION-FREQUENCY: AUBURN DAM SIMULATION (WATER YEARS 1905-1986)
ELEV IN FEET MSL
850
800
750
700
650
600
550
500
450
99.99
99.9
99
90
50
10
5
2
1
.5
.2
.1
.05
.02
.01
PERCENT OF TIME EXCEEDED
200-YEAR DRY DAM
400-YEAR DRY DAM
200-YEAR MINIMUM POOL DAM


ELEVATION-FREQUENCY: SIMULATION OF 200-YEAR DRY DAM AT AUBURN (WY 1905-86)
ELEV IN FEET MSL
800
750
700
650
600
550
500
450
99.9999.9
99
90
50
10
5
2
1
.5
.2
.1
.05
.02
.01
PERCENT OF TIME EXCEEDED
OCTOBER THROUGH MARCH
APRIL THROUGH SEPTEMBER


ELEVATION-FREQUENCY: SIMULATION OF 400-YEAR DRY DAM AT AUBURN (WY 1905-86)
ELEV IN FEET MSL
800
750
700
650
600
550
500
450
99.9999.9
99
90
50
10
5
2
1
.5
.2
.1
.05
.02
.01
PERCENT OF TIME EXCEEDED
OCTOBER THROUGH MARCH
APRIL THROUGH SEPTEMBER


ELEVATION-FREQUENCY: SIMULATION OF 200-YEAR MINIMUM POOL DAM (WY 1986-88)
ELEV IN FEET MSL
840
820
800
780
760
740
720
700
99.99
99.9
99
90
50
10
1
.1
.01
5
2
.5
.2
.05
.02
PERCENT OF TIME EXCEEDED
OCTOBER THROUGH MARCH
APRIL THROUGH SEPTEMBER

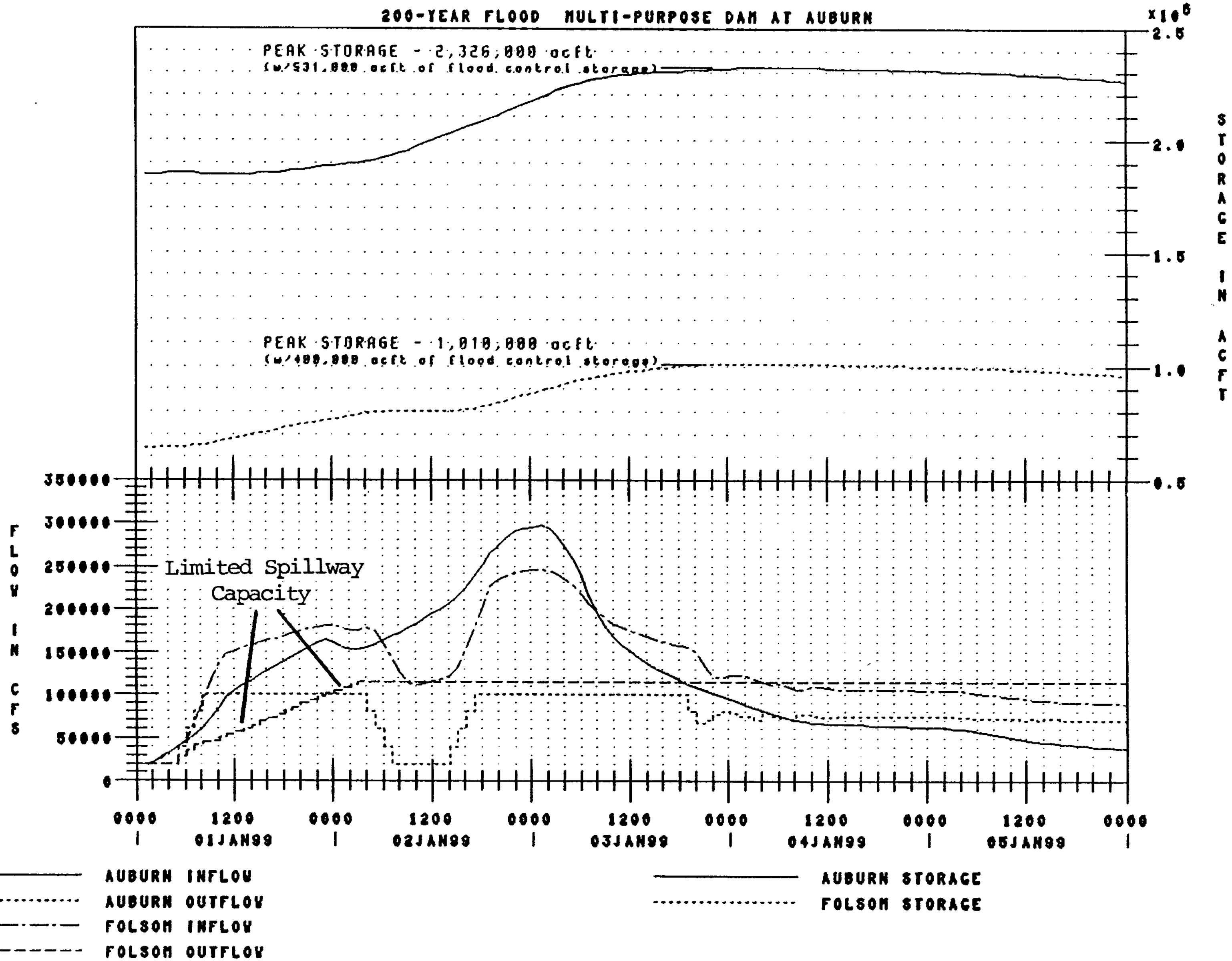

NORTH FORK AMERICAN RIVER AT AUBURN
ELEV IN FEET
900
850
800
750
700
650
600
550
500
450
0
5000
10000
15000
20000
25000
30000
35000
40000
45000
50000
DISCHARGE IN CFS
GATED FLOOD CONTROL OUTLETS (RATING FOR 10-5'X9' SLUICES)



NOTES:
1. Dam located at River Mile 20.1 designed to control a 200-Yr. flood with 400,000 ac.-ft. of flood control space in Folsom Lake and a 115,000 cfs objective release.
2. Top of inactive pool - elevation 490.
3. Curves define the duration of time elevation is equalled or exceeded
4. Curves reflect operation with addition of 10-5'X 9' gated outlets.

ELEVATION-
FREQUENCY-DURATION
AUBURN DRY DAM ALTERNATIVE
(200-YEAR DESIGN)

U.S. ARMY CORPS OF ENGINEERS
SACRAMENTO, DISTRICT



GPO 685-223/40504